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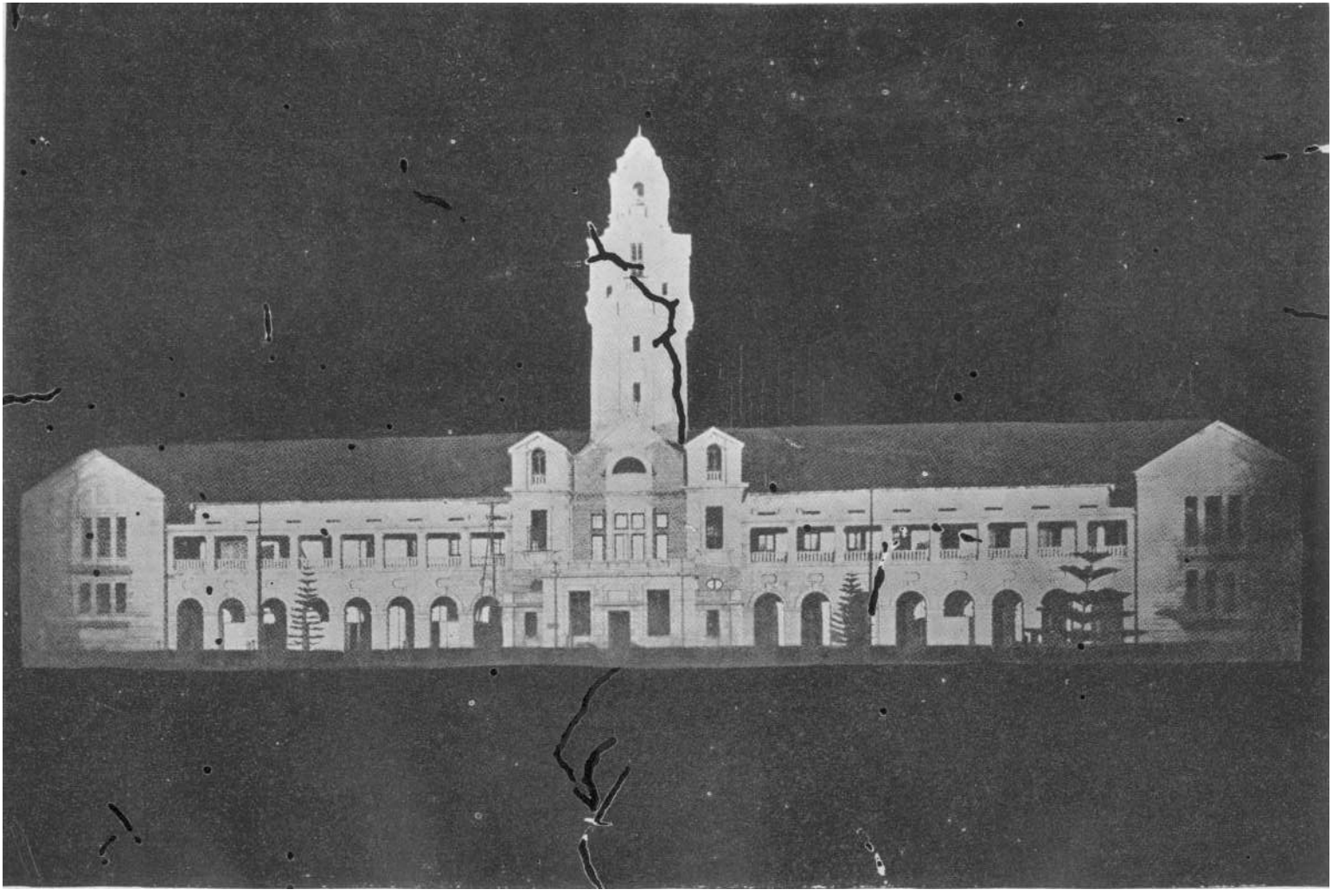

INDIAN INSTITUTE OF SCIENCE

1938—1948

BANGALORE
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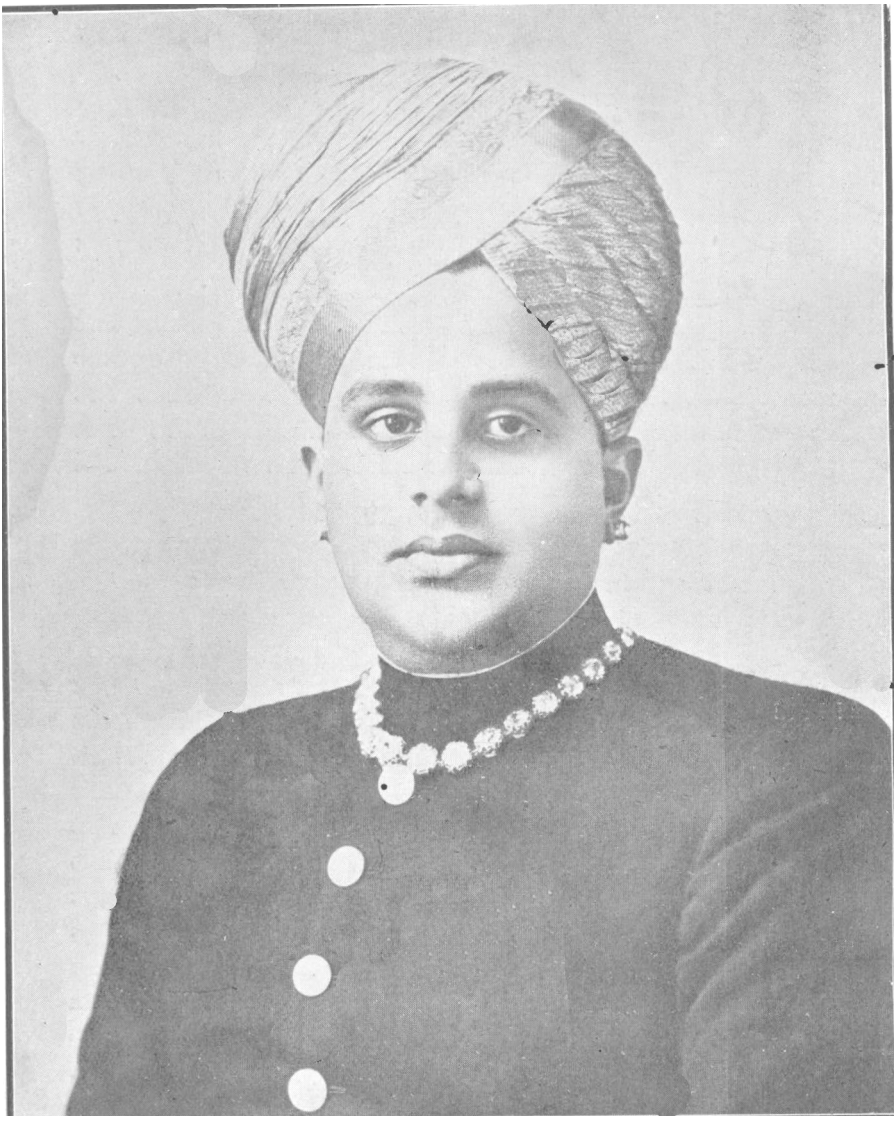
THE HON'BLE PANDIT JAWAHARLAL NEHRU

This handbook is issued as a special volume on the occasion of the visit of the Hon'ble Pandit Jawaharlal Nehru, Prime Minister of India, to the Indian Institute of Science on 17th December 1948. Pandit Jawaharlal Nehru has kindly consented to lay the foundation-stone of the new building for the Department of Electrical Communication Engineering and open the Scientific Exhibition at the Institute.

The Institute owes its origin to the endowment made by the late J. N. Tata in 1896. Its work commenced in July 1911. This volume is issued to provide a compendium of information on the history and growth of the Institute, the work of the Departments during the last decade, and the exhibits arranged in the Exhibition.



His Highness
SRI JAYACHAMARAJA WADIYAR BAHADUR, G.C.B., G.C.S.I.
Maharaja of Mysore

PREFACE

In the modern world, Science is so closely woven into the fabric of the life of people that it is no longer to be considered the preserve of serious-minded intellectuals at universities and research institutes, nor the handmaid and tool of industrialists with their mysterious powers and fabulous millions. Through its methods, its achievements and still more, its potentialities, it has become a social force of such great consequence that peoples and Governments in all countries are continually becoming more science-minded and giving ever-increasing attention to problems of science. The use of "atom bomb" and the threat of "bacteriological warfare" towards the close of the world war has roused in the minds of peoples a vivid awareness and apprehension of the power and consequences of applied scientific knowledge. There is also the widespread appreciation that largely through science and the applications of scientific knowledge only can come about the raising of the standard of living and the freedom from want and disease of the common man.

Emphatic expression has been given to this changed outlook in the leading countries. An Australian scientist, who visited Russia in 1945 at the instance of his Government, wrote, "....It can be said without fear of contradiction that nowhere else in the world, not even in America, is there such widespread interest in science among the common people, as there is in Russia. Science is kept before the people through newspapers, books, lectures, films, exhibitions in parks and museums and through frequent public festivals in honour of scientists and their discoveries."

Of current thought towards scientific development in England, the following comments are characteristic:

"It is admitted that Britain has been spending relatively far less on science than other major countries.....unless Britain takes steps now to increase the total expenditure to at least 1 per cent. of the national income, then in ten to fifteen years' time, when the effects of the increased expenditure of the other countries

become apparent, British science will be found to have lagged and Britain might become a third-rate power."

In America, people are too well aware that, in the recent war, victory which meant so much for their destiny was achieved only by utilising scientific and technical resources to a larger extent than in any other country. That nation has firm hold of the conviction that superior technology, superior research and superior production should not only be available in a war emergency but they should be integrated in a peace-time counterpart with military requirements for national security and prosperity.

It is against this background that we are called upon to plan and develop scientific work in India. To make the people "science-conscious" and "science-thrilled" should be the all-important and absorbing task. In this land of ancient culture to endow science as in Russia with the authority of religion is doubly blessed; it will ennoble religion and enrich science.

The idea of holding exhibitions of scientific work is by no means new. It is regularly adopted by many leading institutions in Europe and America. In a research institute like the Indian Institute of Science which is engaged in pure and applied scientific research, a presentation of the important investigations and work, besides attracting interest of a wide circle of persons among the public, facilitates amongst the workers of the various departments of the Institute a closer understanding and co-ordination of scientific work, and renders possible an overall synthesis of scientific progress. The organization of an exhibition of this character for the first time has involved much labour and thought and these have been unstintedly given in the co-operative efforts by all concerned at the Institute, staff, students and research workers. An attempt is made in the following pages to present an humble account of the progress of a scientific institution (which owes so much to individual philanthropy) over an eventful decade before the public.

24th December 1948,
Indian Institute of Science,
Bangalore 3 (*South India*).

E. V. GANAPATI IYER.

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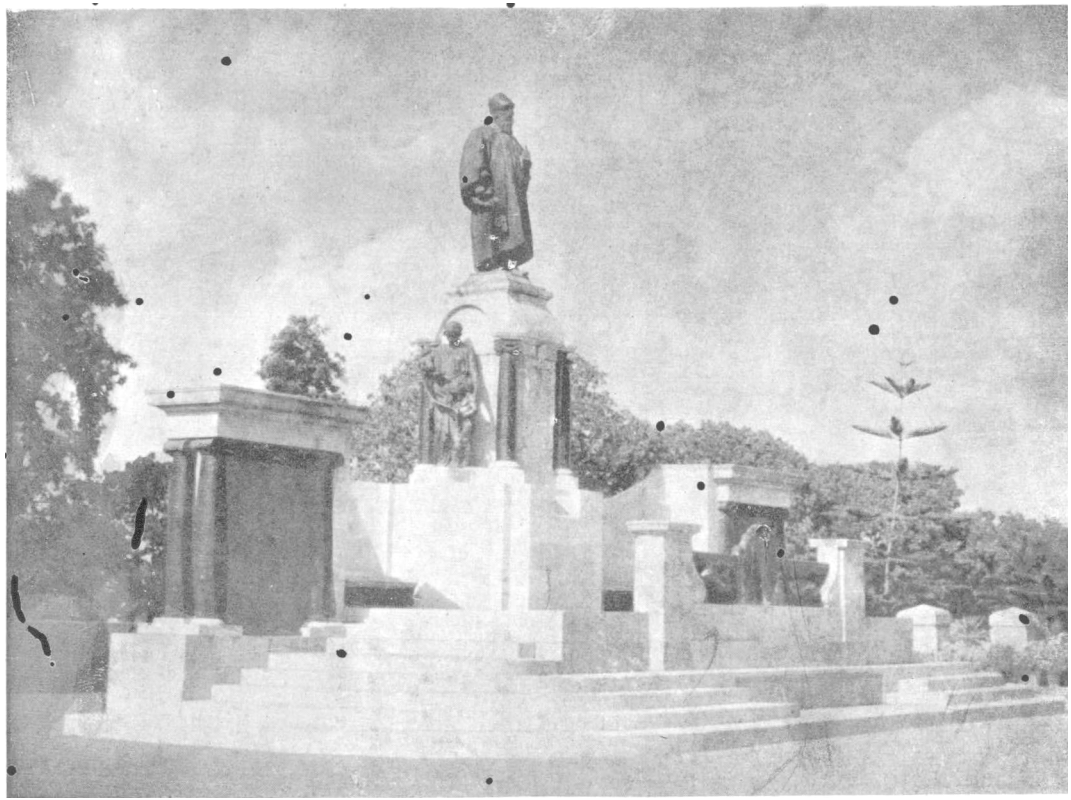


The Founder

GENERAL

The Indian Institute of Science, Bangalore, has the distinction of being the first institution organised in India with the specific purpose of furthering advanced research work in pure and applied sciences. Its establishment was actually formulated in 1886 and, after a long examination of details by experts, it began to function in 1909 and the first students were admitted in July 1911. In the terms of the Government of India Resolution, "The object of the Institute shall be to provide for advanced instruction and conduct of original investigations in all branches of knowledege and, in particular, in such branches of knowledge as are likely to promote the material and industrial welfare of India."

Historical Sketch

A short historical account of the establishment of the Institute may here be given, not only as an appreciation of the work of the personalities involved, but also for guidance and furtherance of future effort. The Institute owes its establishment to the munificence of that courageous and prescient son of India, the late Jamshetjee Tata, who has been described by the great writer, Mr. Lovat Fraser, as "in some respects the most remarkable Indian of his time". Mr. Jamshetjee Tata, while very young, had the genius to see that India must add industrial development and the utilisation of its natural resources to its immemorial adherence to the soil and his articles of faith were that, with its abundance of raw material and cheap labour, the country might develop great manufactures, and that Indian brains and Indian capital wisely associated where necessary with Western experience ought to do the work. In Lovat Fraser's words, written in 1911, "Although he was a Parsee and his interests were centred in Bombay, his spirit rose above the restraints of race and creed. He belonged to the whole country and did more for its material regeneration than any Indian of modern times".

Of the three great schemes with which Mr. Tata's name is chiefly associated, *viz.*, the foundation of the Indian Institute of Science, the production of Hydro-Electric power from the heavy

tropical rainfall on the western ghats and the Iron and Steel Industry of India, the first is, perhaps, in some respects, the most significant one. Having these schemes in mind, it was Mr. Tata's good fortune to have come into contact with two great administrators, in whose hearts these schemes struck a very sympathetic cord, namely, Lord Curzon, the then Governor-General of India and Sir K. Seshadri Iyer, then Dewan of Mysore.

Mr. Tata offered property then worth two hundred thousand pounds—which has since increased considerably in value—as an endowment for organising an institution wherein the best intellects of the country should come into close touch with Western Science and find new careers in industry and the development of the resources of India should be forwarded. A scheme was laid before Lord Curzon on the day after his arrival in India and the same secured his warm support. Sir William Ramsay, the great British scientist, tendered advice upon the scheme and the Mysore Government readily came forward with material assistance for its implementation. The Institute was accordingly established at Bangalore as a post-graduate institution for the promotion of advanced studies and original research. Since then it has considerably progressed in several directions.

Development

The growth and development of notable scientific institutions for advanced studies and research in science and technology in leading countries of the world such as the Imperial College of Science and Technology, the National Physical Laboratory and the Royal Aircraft Establishment in England, the California and Massachusetts Institute of Technology in the United States of America, the Kaiser-Wilhelm Institute in Germany have served to furnish the lines for its expansion and service to the cause of science and industrial welfare of India. To Dr. M. W. Travers, who was the first Director, the Institute owes its sound foundations on which it has built up substantial progress in manifold dirctions.

Departments

When the Institute commenced work in 1911, it opened with the Department of General Chemistry, Applied Chemistry and

Electrical Technology. The Department of Organic Chemistry was added on almost immediately after, in the same year. The Department of Biochemistry was opened in 1921 in recognition of the numerous economic problems which required scientific consideration in this country and which fell within this branch of knowledge. The Department of Physics was added later on to emphasise work in the domain of pure science, which has always been considered to require as much recognition, if not more, as applied science. While minor additions were made, no important developments could be made for some time, owing partly to financial stringency and partly to the intervention of the war.

Recent Additions

One of the effects of the recent world war has been to awaken in the minds of industrialists and Governmental authorities in the country a quickened perception of the importance of considerably increasing the available facilities and variety of advanced instruction in science and technology. During the war period, the situation necessitated a close collaboration of the Institute in various scientific investigations and technical processes with the Defence Services. The assistance rendered by the Institute in problems pertaining to communication engineering, electrochemical production, and food products, etc., has been greatly appreciated by the Government Departments. It was only to be expected that with the successful termination of the war, further expansion of the Institute would require to be proceeded with a pace, with special reference to new fields of technology. The Departments of Aeronautical Engineering, High Voltage Engineering, Internal Combustion Engineering and Metallurgy among the Engineering group and Chemical Engineering, Electro-Chemistry, Pharmacology, Fermentation and Food Technology in the Chemistry group, have been recently added on.

Notable Researches

In the following chapters, an account is given of the activities and researches over the last decade of the several Departments. In this chapter only a brief survey of the overall progress is given. The comparatively short period which has elapsed since the

laboratories were made ready for the reception of students, roughly thirty-seven years, has been fruitful of substantial results. It should first be remembered that the Institute is a post-graduate University institution having for its particular object the promotion of advanced studies and original research with special regard to the educational and economic interests of India. Though its scope is not in any way limited by its constitution which is the one main difference between the Institute and the Universities in this country, it has been the policy of the Institute primarily to make provision for study and research in such branches of pure and applied science as are more directly applicable to Indian arts and industries. At the time of its foundation, the opportunities offered to post-graduate students for instruction in methods of research at Indian Universities were slender and it may be claimed for the Institute that it has trained a considerable number of young Indians in such methods and has equipped them to assume positions of responsibility in the various branches of industrial activity which their country offers. Moreover, the subjects of study have not been limited to those arising from various branches of industry but have included several researches of purely scientific interest, thus enabling many students to assume academic positions on leaving the Institute.

Achievements

The Institute has done yeoman service to the progress of several major industries in India such as wood distillation, essential oils, production of transformers and electrical equipment, soap and hydrogenation of oils, economic utilisation of sewage waste, etc., besides training experts in the various branches of pure and applied chemistry, biochemistry, electrical technology and aeronautical engineering. During the war time, the Institute manufactured and supplied hydrogen gas on a large scale to the Air Headquarters, rennet, modified shellac, pituitrin powder and extracts in ampoules, thyroid powder and calcium gluconate to the Army authorities; made arrangements for the training of War Technicians, undertook the calibration and repair of instruments and carried out special research work for the Army and Air Forces Units. undertook preparation of food concentrates and devised methods for preservation of food grains.

In short, the activities of the Institute are directed in addition to work in pure science towards those problems of applied science as are likely to promote the material and industrial welfare of India and would contribute to a better standard of living for the nation.

The number of students in all the Departments of the Institute, including Diploma courses and the research workers has increased from 187 in 1938–39 to 205 in 1943–44 and 220 in 1947–48, while the number of Division I Staff has increased from 21 in 1938–39 to 48 in 1947–48.

Work of the New Departments

Power Engineering Department.—Mention may be made of the Department of Power Engineering which will incorporate also a High Voltage Engineering Laboratory of the most up-to-date kind. The lay-out and installation of the Department have been designed by some of the best technicians in India involving a capital investment of over 80 lakhs of rupees. The Department which is expected to function from the academic session of 1950 will probably be the most advanced training centre in India in electrical engineering.

Aeronautical Engineering.—The Aeronautical Engineering Department bids fair to be the counterpart in India of the Farnborough Establishment in the U.K. especially with the facilities available to it from the existence of the Hindustan Aircraft Ltd., a proposed Civil Aviation Training School, and an up-to-date Communication Engineering Department; the Aeronautical Engineering Department affords good facilities for training and research in aircraft design and aerodynamics.

The Department provides an advanced scientific and technical training, preparing students to be fit for leadership in Indian aeronautics in the various fields where it may develop in future in industry, civil aviation, the Universities and Technical Colleges, and the Services.

This is the first and only provision in India for a training in aeronautics on lines parallel to those in Europe and America. It is a post-graduate course of theoretical and experimental training supplemented by training in aeroplane factory work. Contact

is maintained with Hindustan Aircraft Ltd., the premier aircraft industry in India, located about 10 miles away.

The aim of the teaching is to build up a sound knowledge of the general principles of aeronautics, and to study the modes of application of these principles to aircraft design and to scientific research. Experiments in the Wind Tunnel and laboratories further emphasise these principles and their applications.

The course of study is divided into two branches: (1) Aerodynamics, and (2) Structures and Design.

Students gain practical experience in various departments of Hindustan Aircraft Ltd., Transport, Power Plant, Engine Assembly, Aeroplane, Accessories, Aeroplane Overhaul Inspection, Radio and Instrument installation, Production Engineering, Cables and Plumbing, Field service.

Metallurgy.—The existence of a well-established and up-to-date geological department in Mysore State and the proximate existence of the well-known ferrous and non-ferrous mining and metallurgical industries, have provided justification of and valuable scope for the training facilities in the Metallurgical Department being made as practical and full as possible. The Department has just started work and the initiation and promotion of research into important problems in Metallurgy are kept in view.

For the full industrial development of India, the exploitation of the extensive mineral resources of this sub-continent is essential.

The importance of "metallurgy" in this connection has been fully recognised by the Central Government who are providing extensive research and development facilities at the National Metallurgical Laboratory, Jamshedpur. It is one of the objectives of the Department of Metallurgy, Indian Institute of Science, to provide suitable personnel for filling the higher technical and scientific posts both at the National Metallurgical Laboratory and at other Indian institutions when a demand arises.

For the three-year Diploma course in Metallurgy at the Indian Institute of Science, about ten post-graduate students (not usually lower than first class Honours standard) are to be enrolled per annum. Although building materials and laboratory equipment

have been difficult to obtain, it was found possible to commence the training of the first batch of twelve students in July 1947.

An entirely new laboratory building (about 15,000 sq.ft. floor area) has been constructed in the grounds of the Institute to house the new Department.

The total capital expenditure for building and equipment will approximately be four lakhs of rupees which have mostly been provided by the Central Government of India. The new Department thus owes its birth mainly to the magnanimity of the Government of India.

Internal Combustion Engineering Department.—The buildings for the Internal Combustion Engineering Department are nearing completion and include a Research Laboratory, which has been provided with modern equipment. The courses in this Department will provide (1) Theoretical and practical instructions in internal combustion engineering and (2) Training in research methods and the undertaking of researches relevant to the subject. The question of the Department functioning as the National Testing Laboratory is under consideration.

Internal combustion engineering has the largest possible scope for expansion and significance for our country, especially in the field of application of motive power to agriculture, irrigation and water supply.

Library

The Institute has one of the best-equipped libraries of scientific and technical books and publications and also provides facilities for the study of European languages. Liaison with industry and assistance is afforded by helping in the investigations of industrial research problems and through co-ordination with Research Boards, Manufacturers' Associations and scientific and technical societies.

Diplomas Awarded

The Institute awards Diplomas in the following subjects:—

1. Aeronautical engineering,
2. Electrical technology,
3. Electrical communication engineering,

4. Internal combustion engineering,
5. Metallurgy,
6. Chemical engineering.

Besides the above Diplomas, the Institute awards the Associateship and the Fellowship of the Institute on the basis of theses submitted by the students incorporating their work.

The Government of India have been pleased to recognise the Associateship and the Fellowship of the Institute as equivalent to the M.Sc. and the D.Sc. degrees respectively of an Indian University.

The Diploma of the Institute has been included as one of the accepted qualifications for recruitment to technical posts under the Central and the Provincial Governments.

Endowments Invited

Whilst the income from all sources suffices for the present requirements of the Institute, it is the intention of the Institute to develop its scope by opening new departments as opportunity offers, and by consolidating and extending the operations of existing departments. Considerable funds will be necessary for this purpose and it is greatly to be hoped that wealthy patriots will be induced by the substantial work which has been already accomplished by the Institute to emulate late Mr. Tata's noble example, and to endow it with liberal funds. The devotion of such funds to providing the intellectual equipment for the pursuit of scientific inquiry and for the development of Indian natural resources by Indians is a purpose which must appeal to every patriot.

Tasks Ahead

With the coming in of freedom, India has added responsibilities in the field of scientific instruction and training. With the collapse of Japan, India has not only to provide her own requirements of technical personnel and scientific man-power, but has also to serve largely the needs of the new sister nations of Asia. It has been commonly recognised that this is a matter requiring the highest priority. The improvement in the economic standard of living of the people of India can be secured only through the labours of our scientists and technical men who

constantly work towards the objective of the fullest exploitation of nature's resources.

We are grateful that the National Government is fully alive to this and has been acting with great rapidity and vigour. Several National Laboratories for Metallurgy, for Physics, for Leather, for Glass and Ceramics and for Chemistry, have already been decided upon on the most up-to-date lines. The marked expansion of this Institute itself, and the programme of further expansion generally approved by the Government of India, are a clear token of its solicitude and interest in scientific instruction. It is fortunate that in the Prime Minister of India at the present critical time, we have in the person of Pandit Jawaharlal Nehru, one of the most enthusiastic and far-sighted votaries of scientific learning and research. Under these happy auspices, the Institute looks forward to a career of increasing usefulness to the country.

Periodical Review

The problems of administration and finance are no doubt becoming complex for us with these large schemes of development. We have, as part of our organisational regulation, an arrangement for introspection, review and self-adjustment, in order to remain in the vanguard of scientific progress and to afford scientific training of the most up-to-date kind in the world through quinquennial Reviewing Committees, consisting of international experts, which are appointed by His Excellency, the Governor-General of India, as the Visitor. Such a Committee, has recently completed its labours to advise us regarding our set-up, to meet the post-war needs of the country.

Along with the Government of India, the Government of Mysore has continuously kept up an active interest in the progress of this premier scientific institution. Right from the beginning the Government of Mysore have been very liberal and given generous help to this Institution both in its organisation and in its subsequent development. On its part, the Indian Institute of Science has co-operated and contributed considerably to the industrial progress of the State. Amongst the notable works done for this State may be mentioned the investigations done in connection with the establishment of the sandal oil distillation and wood

distillation industry in the Mysore State as also of other industries like the soap industry, manufacture of electrical transformers, etc. The Government of Mysore have in recent years afforded assistance to meet the expenses of the Internal Combustion Engineering and Metallurgy Departments, but further development of these Departments in order to provide up-to-date instruction is urgently called for and the help of the Government of Mysore towards the expansion is requested. The Institute earnestly solicits support, financial and otherwise, from other Provincial Governments and industrialists for its expanding activities.

PURE AND APPLIED CHEMISTRY

GENERAL CHEMISTRY

The General Chemistry Section has been paying equal attention to research both in pure and applied sciences. Emphasis on research in each of the two fields of activity, however, has varied from time to time. Since 1939 a more extensive development of applied research was undertaken. A large number of schemes sponsored by the Council of Scientific and Industrial Research, Delhi, are also being investigated at the Section.

A general survey of the main lines of investigation in the General Chemistry Section is given below and is followed by notes on the exhibits.

(*a*) *Inorganic and Mineral Chemistry*

A subject of systematic study has been the geo-chemical origin of minerals, the minerals studied so far being garnets, fibrous tourmalins and certain granites. The valuable deposits of phosphatic nodules of Utatur, Trichy District, Madras Province, have been extensively investigated. A process has been developed for the utilisation of celestite which is found as an admixture in the nodules. The utilisation of the nodules in the manufacture of superphosphate, phosphorus, and ferrophosphorus has been successfully accomplished, after systematic investigations.

Extensive studies are being made on the beneficiation of minerals. Very encouraging results have been obtained with graphite. Gypsum and phosphatic nodules are among the other minerals whose beneficiation is being attempted. In view of the limited sulphur resources of India, the recovery of sulphur from sulphur-bearing minerals has received special attention in the Section. The thermal decomposition of iron pyrites has been studied. Investigations are now being carried out on the reduction of sulphate minerals to yield sulphur.

An important subject of study is the production of beryllium oxide from beryl. Among other industrial problems that have

been studied, mention may be made of the large-scale production of potassium chlorate, barium chlorate, sodium cyanide, cryolite, sodium hydrosulphite, hydrogen peroxide, titanium dioxide, carbon disulphide and anhydrous magnesium chloride. The separation of tantalum from its usual associates—niobium and titanium—has been successfully accomplished. A systematic study has been made of the heteropoly acids of niobium and tantalum. Certain refractories are being studied. Abrasive wheels have been prepared with considerable success, from corundum and silicon carbide.

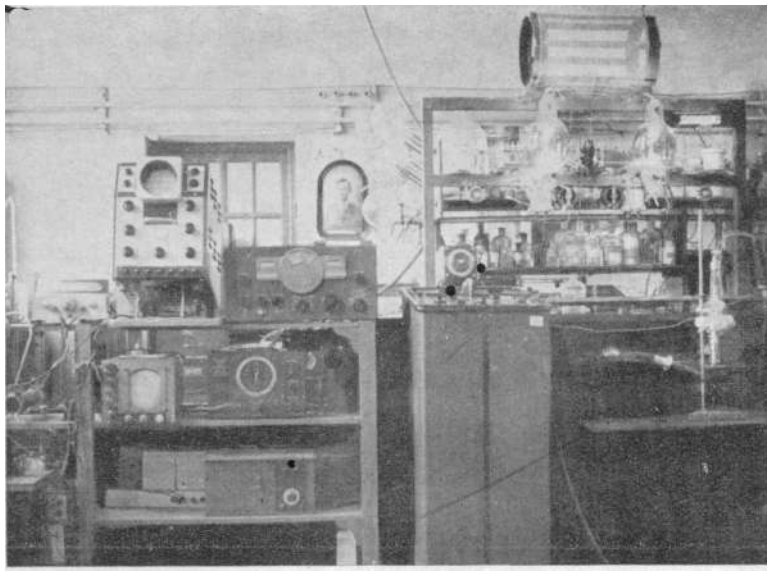
Exhibits.—(Inorganic and Mineral Chemistry):

(1) *The production of sodium hydrosulphite by electrolytic process.*—The work carried out on the production of solid sodium hydrosulphite by the electrolysis of sodium bisulphite solution is demonstrated. Sodium hydrosulphite is used in the Indian textile industry in considerable quantities.

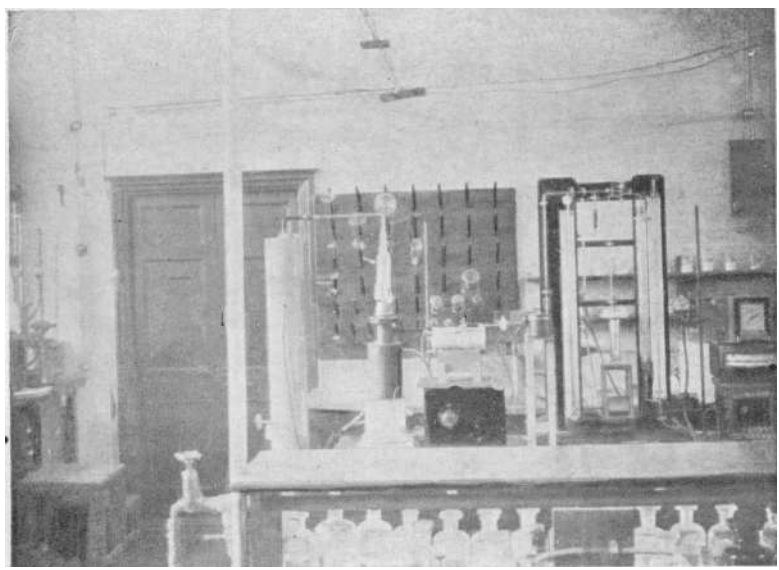
(2) *Chemical analysis with the aid of the Polarograph.*—The Polarograph is a valuable tool in the rapid analysis of chemicals. It has been found to be useful in the estimation of penicillin, fruit sugar when admixed with cane sugar, dextrose and other sugars, thiamin, and ascorbic acid. The polarograms obtained in estimating the above substances are exhibited. The use of the polarograph in rapidly analysing minerals like chromite or copper pyrites is illustrated.

(3) *Kaolin and its purification.*—In the course of a survey of the physico-chemical properties of samples of kaolin from different parts of the Mysore State, marked differences in physico-chemical properties were noticed. With the kind co-operation of the Government Porcelain Factory, Bangalore, a correlation between the properties of kaolin and its suitability for the manufacture of porcelain is being established and improved methods of purifying kaolin are being studied. The lines on which the investigations are being carried, are demonstrated.

PLATE 1

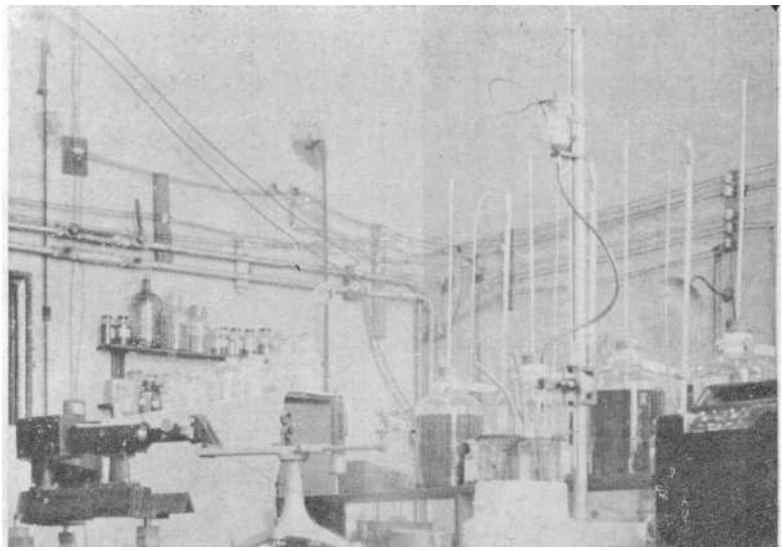


Production of microwaves

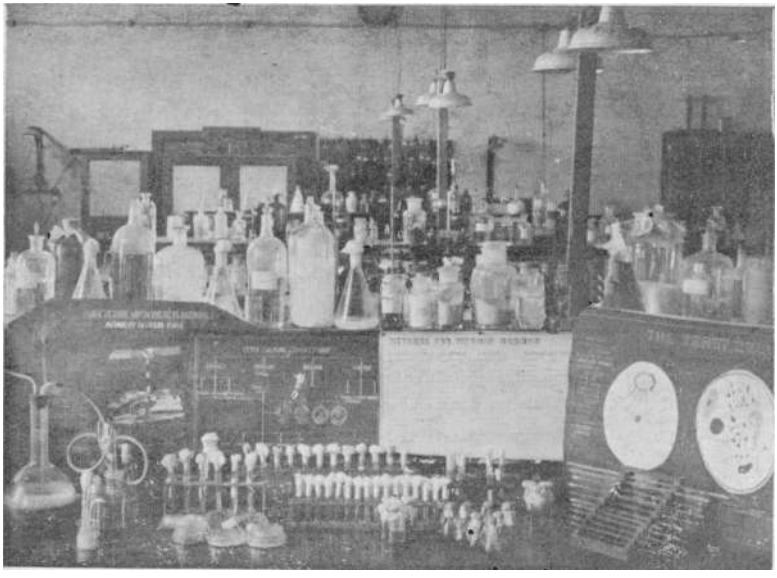


Study of gas adsorption on catalysts

PLATE II



Polarograph and optical instruments



Fermentation Technology Laboratory

(*b*) *Dielectric Constants*

The dielectric constants of gases, liquids and solids have been extensively studied in this laboratory for the last twenty years. The results have yielded valuable information regarding the size, shape and structure of certain molecules—notably of high polymers. Recent work on the dielectric constants of liquids and solids has brought to light valuable information on the ferroelectric phenomenon.

Another field of investigation has been ultrasonics. Ultrasonic velocities in gases and vapours are being carefully measured, using apparatus specially designed for the purpose, in this laboratory.

Exhibits.—

(1) A specially constructed apparatus, of simple design, for the measurement of dielectric constants is shown.

(2) *Microwaves.*—The object of the exhibit is to demonstrate the propagation of very short electromagnetic waves in metallic tubes in relation to the measurement of dielectric constants of solids, liquids and solutions. A wave guide standing wave system is exhibited which clearly shows the short waves employed. The exhibit shows a 3 cm. wave system built in the laboratory for the study of absorption in ammonia.

(3) *Nuclear Magnetism.*—The experiment is intended to give a visual presentation of the signal due to a most important property of an atomic nucleus, namely the magnetic moment. The signal is presented on the screen of a cathode-ray oscillograph. The technique which is simple has also been developed in this laboratory.

(4) *Ultrasonics.*—One of the exhibits on ultrasonic research is an experimental apparatus for the measurement of ultrasonic velocities in gases and vapours. An experiment shows how the velocity is measured in gases. The other exhibit is a high-power quartz crystal oscillator constructed in this laboratory. The oscillator is used to demonstrate the production of intense sound waves of high frequencies. Effects of the intense sound waves are demonstrated.

(5) *Potentiometric titration of complex compounds.*—The exact chemical composition of Prussian Blue or Turnbull Blue is not known. The potentiometric titration in which the oxidation reduction potentials are measured as the composition of the reactants are varied, indicates by sharp changes in potentials the exact composition of such products.

(6) *Hydrogen peroxide.*—The production of hydrogen peroxide of 10, 30, 100 and 200 volumes on a pilot plant scale is shown. Hydrogen peroxide is used not only for medicinal purpose but also for bleaching of textiles. 300 volume hydrogen peroxide has been used in V_2 rockets.

(*c*) *Physico-chemical investigations on oils and fats*

Refraction dispersion of oils and fats has been studied. Extensive work has been carried out on the catalytic splitting of oils and fats and on the hydrogenation of oils by the continuous process.

The liquid obtained from the shells of the cashew nut is of considerable economic importance, nearly 30,000 tons of this liquid being available in India. Investigations on the liquid, conducted in this laboratory, have yielded valuable baking enamels for wires, bobbins and cycles. A water-proof varnish possessing high gloss has been obtained from castor oil.

Vegetable oils, such as castor oil, are increasingly being used in the plastic industry. Investigations in this laboratory have resulted in the production of octyl alcohol, sebacic acid and ethyl ricinoleate on pilot plant scale.

Exhibits.—Products obtained as a result of the above investigations are exhibited.

(*d*) *Plastics*

Systematic work on plastics of different types has been undertaken, and notable results have already been obtained. The chief investigation in this laboratory, in this field, is the preparation of vinyl plastics from power alcohol and chlorine.

Exhibit.—The pilot plant set up for the production of ethylene and its dichloride (the first stage in the production of vinyl plastics).

(*e*) *Colloid Chemistry*

The physico-chemical properties of rubber latex and the production of chlorinated rubber have been extensively studied and valuable information of practical importance has been obtained. Adsorption on active charcoal and on silica gel from binary mixtures has been investigated. A detailed study has also been made of the depolarisation of light in certain colloidal systems. Cataphoretic speeds of metallic sols have been studied. Activated carbon has been produced on a fairly large scale.

Exhibits.—Protective lining of rubber and chlorinated rubber.

(*a*) Equipment suitably lined with rubber is in great demand in chemical industries for handling corrosive liquids and abrasive slurries. For example, the manufacture, storage and distribution of hydrochloric acid require rubber-lined equipment. Rubber-lined mixing tanks are used in the manufacture of commercial bleach. Such tanks are also used in the pickling of iron and steel and in the paper industry.

Methods have been developed in this laboratory for lining with rubber, mild steel and wooden articles. Corrosion and abrasion tests performed with these rubber-lined test-specimens have been very promising.

(*b*) *Chlorinated rubber coatings.*—Chlorinated rubber has come into prominence recently as an anticorrosive material. A successful method for the preparation of chlorinated rubber from rubber latex has been developed in this laboratory. The product can be used in the following industries on account of its anticorrosive, protective and bactericidal properties: (1) Anticorrosive lining for the equipment employed in paper industry, (2) Masonry paints, (3) Metal finishes, (4) Improving the chemical resistance of varnishes, (5) Marine paints, (6) Exterior house paints, (7) Furniture lacquers, (8) Water-proofing fabrics and (9) Adhesive and lacquer emulsions.

(*c*) *Flotation of Minerals.*—Flotation is a valuable process for the beneficiation of ores. The process consists in mixing the powdered ore with water and certain reagents and feeding the pulp to a flotation cell. Air bubbled through the slime produces a froth which carries over certain ingredients of the mineral into the collecting chamber, thus beneficiating the ore.

The success of flotation depends on the proper choice of reagents used in the process and careful laboratory investigations are necessary before a mineral can be successfully beneficiated by flotation. The nature of these investigations is illustrated with particular reference to the use of "collectors" in modifying the contact angle of the mineral.

(*f*) *Electrochemistry*

The behaviour of certain metal-metal oxide electrodes, the anodic deposition of protective coatings on aluminium and the preparation of carbon electrodes for use as depolarisers in dry cells received attention. A detailed study was made of electrical conductivity in triethanolamine solutions. The electrolytic preparation of sodium and magnesium was extensively studied, in collaboration with the Department of Electrical Technology of the Institute. Interesting results were obtained with porous carbon electrodes in electrolytic reduction and oxidation processes. Benzene, for instance, could be efficiently oxidised to *p*-benzoquinone.

(*g*) *Industrial catalysis and high pressure synthesis*

The production of liquid hydrocarbons from carbon monoxide and hydrogen—a subject of great practical importance—has received considerable attention and various catalysts that can be employed for the purpose have been carefully investigated, in collaboration with the Chemical Engineering Section. The physical properties of the catalysts are examined and a correlation sought between these properties and their efficiency as catalysts in the Fischer-Tropsch synthesis.

Synthetic methanol is also receiving full attention. Among other catalytic processes studied, mention has to be made of the formation of diolefines from mono-olefines, the production of

butadiene from ethyl alcohol and of allyl alcohol from glycerine.

The laboratory for work on gases under high pressure is being rapidly fitted up and certain investigations have been started.

Exhibits.—

(1) *Formaldehyde from methane (Sewage Digester Gas).*—The methane-air mixture containing the catalyst (oxides of nitrogen) is, after preheating, passed through the reactor tube. The effluent gases after being scrubbed to remove the formaldehyde, are recirculated.

(2) Exhibits regarding synthetic methanol and Fischer-Tropsch synthesis have been arranged in collaboration with the Chemical Engineering Section. For details please refer to exhibits under Chemical Engineering.

(*h*) *Study of the kinetics of gaseous reactions and study of adsorption of gases on catalysts*

In recent years, two distinct types of research have largely contributed to the advance in our knowledge of heterogeneous catalysts. One is the study of the kinetics of suitable reactions at appropriate surfaces. This has enabled us to compare the energies involved when the process occurs at surfaces and when it occurs homogeneously in the gas phase. The other method of study—which pays more attention to the surface than to the reaction itself—involves measurement of adsorption. Both these lines of investigation have been carried out in this laboratory. Adsorption from a mixture of gases on industrially important catalysts has, in particular, been systematically studied.

Adsorption of gases at high pressures.—A volumetric method has been developed for studying the adsorption of gases at pressures of the order of 100 atmospheres. The adsorption of nitrogen and hydrogen on synthetic ammonia catalysts has been studied at these pressures by the new technique.

Application of strain gauges for high pressure measurements.—A detailed experimental study was made of the correlation between static pressures and surface-strains on some spring

steel diaphragms designed for making pressure measurements ranging up to 1,300 p.s.c

Surface-strains were determined by using bonded-wire gauges in conjunction with a Callendar Griffiths type of direct current bridge. The diaphragms were made of a special design to eliminate end-effects.

High accuracy was obtained together with linear relationship between strain-readings and pressure-readings.

From the theory of the bending of moderately thin diaphragms, an expression has been derived for the average strain over the diametral region occupied by the strain-gauge.

Exhibits.—Equipment employed in the above investigations.

2. Fermentation Technology

1. *The National Collection of Type Cultures*:—A collection of micro-organisms of scientific significance and industrial importance sponsored by the Council of Scientific and Industrial Research, New Delhi.

This collection together with other collections at New Delhi, Calcutta and Bombay constitutes one of the world's best collections in the East.

A National Advisory Committee is being constituted to plan the development and co-ordination of these collections. The collection is recognised by the International Union of Biological Sciences and receives a subvention from this source.

2. *Microbiological assay of vitamins, amino acids and other essential nutrients and growth factors*:

Assay of vitamins and amino acids has till recently been carried out with plants and animals—particularly rats. Micro-organisms for which these constituents have been found indispensable are now being utilised for the assay of these constituents. These methods are elegant, rapid, simple and need only micro quantities of research material.

3. *Industrial enzymes:*

This is a research project financed by the Council of Scientific and Industrial Research. Fungal and bacterial diastases have been produced on a pilot plant scale and an application for patenting this process has been filed.

4. *Cytochemical studies of avitaminosis in yeasts and fungi:*

Syndromes of avitaminosis in micro-organisms have been found to occur; they could be artificially induced and abolished by suitable treatment. The antibiotic and zymogen content of fungi and yeasts could be evaluated by cytochemical technique and their biochemical performances predicted.

5. *Studies with the micromanipulator.*—Isolation of single cells and spores of bacteria, yeasts and fungi can be carried out. Microknives, micropipettes, etc., for carrying out these operations are forged by special technique.

6. *Production of high concentration distillery washes.*—This is a research project financed by the Council of Scientific and Industrial Research. By careful selection and treatment of yeasts tolerant to higher concentrations of alcohol, it has been possible to obtain distillery washes containing 12 to 14% alcohol by volume. The present practice in all Indian distilleries results in a concentration of only 6 to 7%.

The process has been demonstrated on a commercial scale both at Daurala and Hargaon and has been covered by two patents. (These demonstrations have shown an overall reduction of 50% in the cost of production of alcohol.) The question of introducing this process in all the distilleries in India is being actively considered by the Council of Scientific and Industrial Research.

7. *Scientific and technological aspects of sweet toddy:*

Sweet toddy (*neera*) has been found to contain most of the vitamins of B-Complex.

Concentrates of sweet toddy can replace malt extract as a sweetening and nourishing vehicle for all the pharmaceutical preparations.

As a source of sugar, sweet toddy from the palm presents many advantages. The perennial nature of the palm, the direct

tapability of the palm without having recourse to the expensive crushing operations indispensable for cane juice and the absence of colouring matter in the palm juice are factors which cheapen the cost of sugar production from this source.

Palm juice constitutes a rich and favourable raw material for all industrial fermentations including the production of penicillin.

8. *Production of antibiotics—penicillin and streptomycin :*

A comparative study in the yields and the production costs of the antibiotics by the surface and submerged methods of growth is made.

9. *Production of citric acid*—a comparative study of the various methods of production.

10. *Utilisation of cellulosic wastes as raw material for power alcohol, particularly begasse*:

Flow sheets describing the process are presented.

11. *Microbiological production of vitamins and vitamin concentrates:*

Ergosterol from special strains of yeasts, B-Complex concentrates from fungi and yeasts, riboflavin (B_2) from bacteria, yeasts and fungi—these are some of the processes at the moment employed.

The processes will be demonstrated.

12. *Physico-chemical methods of investigating microbial metabolism*:

A number of dilatometric, conductometric and manometric methods of studying the metabolism of micro-organisms have been developed. These have won international recognition.

13. *Ultramicro technique:*

The first ultramicro laboratory in the East has been set up in the Fermentation Technology Laboratories. The technique is useful in the study of single cells.

14. *Studies on insect nutrition:*

In these laboratories insects were demonstrated to be successful as test organisms for the assay of vitamins and growth factors.

The nutritional requirements of some of our economically important insects, *e.g.*, lac insect and silkworm, have been taken up for investigation.

The problem of the nutrition of the silkworm in relation to the quality and quantity of silk is one of fundamental importance to the silk industry in this country. A research project covering these studies has been financed by the Government of Mysore.

3. Cytogenetics

Heredity in yeasts

Planned breeding has been playing an important part in the improvement of economically important crop plants. Yeast, though unicellular, belongs to the plant kingdom and its economic importance needs no special emphasis. But planned breeding, as in the case of higher plants, was not possible since very little was known about the behaviour of chromosomes in yeasts. Chromosomes are the carriers of heredity and any advance in our knowledge of the genetics of yeasts is therefore dependent on advances in our knowledge of the chromosomal constitution of the different strains.

A technique was perfected on rational grounds for the demonstration of chromosomes in yeasts and the accidental discovery of a strain of brewery yeast having only two chromosomes rendered rapid advance possible. The chromosomes consist of a linear array of the units of heredity, the "genes", and each organism possesses normally a pair of each of the genes. The performance of the various strains of yeast depends on their genic make-up since genes control, among other things, alcohol and vitamin production.

Mutations or "sports" may be the result of different causes. These could be classified into different types. Variations may be the result of (1) mutation of a gene, or (2) loss or gain of portions of chromosomes or (3) duplication of one or more chromosomes or of (4) entire chromosome sets. A clear distinction between these different types of changes is an essential pre-requisite for any profitable attack of the problem of hybridisation in yeasts. Investigations during the past four years have

rendered possible identification of these various categories of changes in yeasts.

When one realizes that all economically important crop plants have arisen as a result of repeated duplications of the chromosome sets of the original wild ancestor, the induction of a doubling of chromosomes in yeast, by diverse agencies, would appear in the proper perspective. Theoretically, the new strains with duplicated chromosomes should either produce double the quantity of alcohol and vitamins shown by the control, or produce the same quantity in a much shorter time. Studies on the fermentative ability of the new strains with duplicated chromosome sets indicate that though the final percentage of alcohol produced is the same as in the case of the control, there is approximately a 30% acceleration of the rate of fermentation. This has led to the discovery of some new modes of gene action.

It seems likely, therefore, that some of the new strains may be of considerable importance to industry. The planned series of investigations now in progress are expected to add considerably to our knowledge in both the pure and applied branches.

Exhibits.—Living Giant Colonies of new strains produced in this laboratory would be exhibited.

4. ORGANIC CHEMISTRY

Introduction

The activities of the Organic Chemistry Department may be divided broadly into four groups: (1) Researches in theoretical chemistry; (2) Researches in applied and industrial chemistry; (3) Researches sponsored by the Council of Scientific and Industrial Research; and (4) War work.

1. Researches in theoretical chemistry consisted of work in (i) Bicyclic terpenes and sesquiterpenes, including α- and β-santalols; (ii) Studies in bridge formation; (iii) Studies in phenanthrene and cyclopentanophenanthrene derivatives; (iv) Walden inversion; (v) Cantharidin; (vi) Reformatsky reaction; (vii) Studies in sterols; (viii) Studies in rosin; (ix) Studies in chemical equilibrium in butadiene formation; (x) Vapour phase chlorination of aromatic compounds; (xi) Studies with methone; (xii) β-Aryl-

glutaconic acids; (xiii) Studies in cardiac aglucones; (xiv) Stereochemistry of decalins; (xv) Isomeric changes in triazoles and thiobiazoles; and (xvi) Influence of double bond on the stability of heterocyclic systems.

2. Researches in applied and industrial chemistry consisted of (i) Studies in essential oils; (ii) Oils and fats; (iii) Colouring matters; (iv) Insulating varnishes; (v) Plasticisers from Indian turpentine oil; (vi) Recovery of glycerine from soap-lye; (vii) Researches on coal-tar products; (viii) Synthetic drugs; (ix) Natural drugs; (x) Synthetic dyestuffs and dye-intermediates; (xi) Manufacture of commercially useful chemicals and fine chemicals, some on a semi-large-scale basis.

3. The schemes sponsored by the Council of Scientific and Industrial Research consisted of the following nine items:

(1) Manufacture of organo-arsenical compounds.
(2) Preparation of synthetic adrenaline.
(3) Preparation of new antimalarials.
(4) Preparation of novocaine.
(5) Manufacture of nitrobenzene, aniline and dimethylaniline.
(6) Preparation of aromatic chemicals: musk xylol, musk ketone and musk ambrette.
(7) Sulphur compounds from coal.
(8) Production of phenol.
(9) Preparation of coumarin.

4. War work consisted of work on the following:

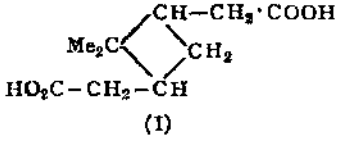
(1) Preparation of atebrin.
(2) Preparation of dimethylaniline from benzene *via* nitrobenzene and aniline.
(3) Preparation of a camouflage dye: *p*-nitrophenyl-azo-β-naphthylamine.
(4) Preparation of an antigas ointment: (2: 4-D.P.B.C.)
(5) Establishment of the conditions for the preparation of some sulpha-drugs, phosphorus trichloride and semicarbazide hydrochloride.

Bicyclic Terpenes

Notable contributions have been made in the synthetic studies of bicyclic terpenes of the pinane, camphane, thujane and carane series.

Pinane group.—sym.-Homopinic acid (I), synthesized from *cis*-diethyl norpinate has been definitely proved to possess a *trans*-configuration and consequently unsuitable for the synthesis of bicyclic terpenes. Attempts to synthesise *trans*-pinonic acid (III) from *trans*-pinic acid (II) lead to the formation of an isomeric pinonic acid, *viz.*, *trans*-1-acetonyl-2 : 2-dimethyl-cyclobutane-3-carboxylic acid.

The first total synthesis of verbenone and a new total synthesis of α- and β-pinenes have been effected starting from *cis*-pinonic acid. *cis-dl*-Pinonic acid has been synthesized starting from *dl-trans*-pinic acid. This synthesis of pinonic acid amounts to a total synthesis of all naturally occurring terpenes of the pinene group.



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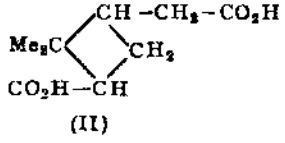

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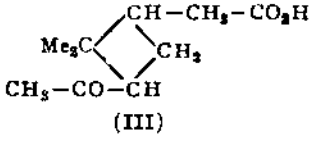

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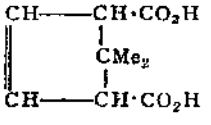
Camphane series.—Homocamphoronic acid has been synthesized starting from ethyl-α-bromoisobutyrate and ethyl lævulinate. This synthesis amounts to a new total synthesis of camphor. In the camphane series isodehydroapocamphoric acid (IV), isofencho-camphononic acid (V), dihydro-iso-lauronolic acid (VI), iso-lauronolic acid (VII), and Manasse's ketonic acid (VIII).



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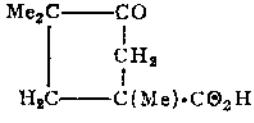

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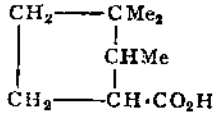

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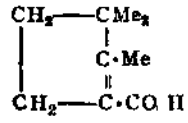

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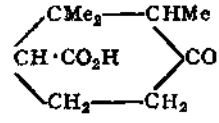

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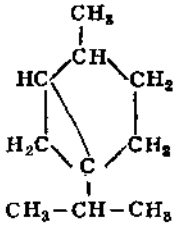
Thujane series.—Thujane (IX) was synthesised (i) starting from 2: 4-dibromo-menthone, and (ii) by building up a cyclopropane ring on an appropriate cyclopentane derivative.

d-*Umbellularic* and *umbellulonic acids*, degradation products of umbellulone (X), were synthesized starting from ethyl α-isopropyl acrylate. The former acid was also synthesized from α-isopropyl-α-(carbethoxy succinate).

Complete synthesis of isothujone and a few other members of this series have been effected.

A total synthesis of thujone (XI) was achieved by converting umbellulonic acid to thujadicarboxylic acid, starting from which thujone had been partially synthesized by Ruzicka and Koolhaas.



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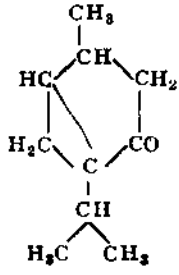

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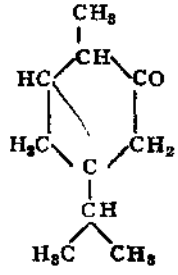

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Carane series.—Caronic acid and homocaronic acid, degradation products of carone were synthesized by condensing dimethyldiazomethane with diethyl fumarate and diethyl glutaconate, respectively.

Carane was synthesized starting from ethyl Δ^1-tetrahydro-*p*-toluate.

Biogenesis of terpenes.—Attempts have been made to explain out the synthesis of terpenes in nature.

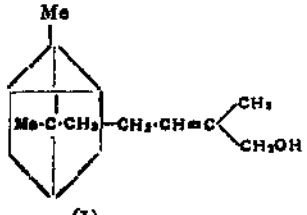
Sesquiterpenes

Synthesis of α-santalol.—The unambiguous synthesis of α-santalol (I) starting from camphor, an achievement in the alicyclic chemistry, places beyond doubt, the structure of

α-santalol and related substances arrived at by Semmler, *et al.* by degradation methods several decades ago. Another synthesis of α-santalol has been achieved starting from tricyclo-eka-santalal (II).

Guerbet's acid and α-santalic acid have been shown to be different, and a probable structure (III) for the former has been suggested.

A new acid $C_{15}H_{22}O_2$ has been isolated from sandalwood oil and has been termed β-santalic acid. α-Santalol has been isolated from sandalwood oil in the purest possible form and from it pure α-santalene has been prepared through the reduction of its chloride.



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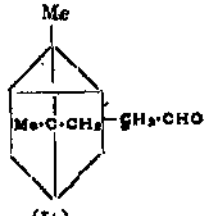

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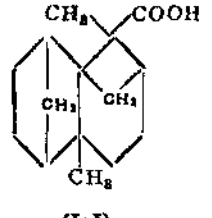
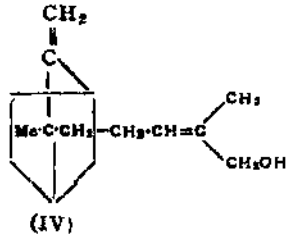


(III)

Synthesis of β-santalol.—β-Santalol (IV) has been synthesized starting from ethyl bicyclo-eka-santalate (V) confirming the structure assigned to it by Ruzicka and showing the formula suggested by Simonsen as wrong.

Bicycloekasantalic acid and its ozone degradation product camphenilonyl acetic acid (VI) have been synthesized starting from camphor.



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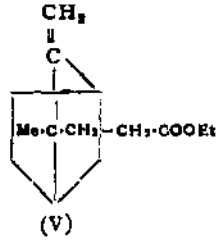

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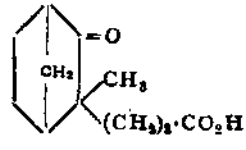

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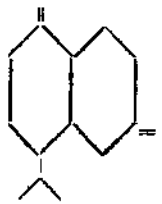
Cadinene group.—Cadalene and *apo*cadalene have been synthesized starting from *p*-cymene.

In order to locate the double bonds and other functional groups in sesquiterpenes of cadinene group all the theoretically possible methyl cadalenes and 1-ethyl-6-methyl-4-isopropyl- and

1-methyl-6-ethyl-4-isopropyl-naphthalenes have been synthesized by the succinic anhydride method to serve as reference substances.

Isolation and elucidation of the structure of cadinenic sesquiterpene present in the essential oil of Hardwickia pinnata.—All dextro-rotatory cadinenic sesquiterpenes have been isolated from the essential oil from the oleo-resin of *Hardwickia pinnata* and has been shown to be a mixture of two isomeric compounds whose constitutions have been established as (VII) and (VIII).



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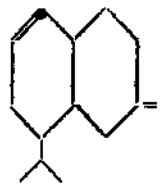


(VIII)

A new reaction.—During these synthetic investigations a new reaction which enables reduction, ring-closure and further reduction of a γ-aryl-vinyl acetic acid to be performed in one operation, instead of three as by older methods, has been discovered. The reaction has been successfully employed in the synthesis of alkyl naphthalenes.

Studies in Rosin

It is now generally believed that resins are produced by condensation and oxidation of essential oils. India is very rich in various types of resin-bearing plants. But with the exception of the turpentine resin, very little work has been done in this country on resins.

Rosin from Shorea robusta.—After determining some of the physical and chemical constants of a genuine sample of *Dhup* obtained from *Shorea robusta*, its ethyl acetate soluble and insoluble neutral fractions, as also the ether soluble and insoluble acid fractions have been studied and a number of products isolated. Chromatographic separation of the component acids of the ether soluble acid fraction has been effected.

Rosin from Pinus excelsa.—The rosin from *Pinus excelsa* has been subjected to destructive distillation and the products isolated and characterised.

Studies in Bridge Formation

Synthesis in the bicyclo-(2: 2: 2)*-octane and bicyclo-*(3: 2: 2)*-nonane systems.*—Baeyer for the first time, tried without success to effect the bridge formation between the two active 1: 4-carbon atoms of succinosuccinic ester by the action of alkylene dihalides like methylene iodide, ethylene bromide, etc., and observed "if a bridge of one or two carbon atoms connecting the *p*-carbon atoms can be obtained successfully, then the substances would be of extremely great interest".

The dry disodium derivative of ethyl succino-succinate by reacting with methylene-, ethylene- and trimethylene-dihalides, have yielded bicyclo-2: 1: 2-heptane, bicyclo-2: 2: 2 octane, and bicyclo-2: 3: 2-nonane-2: 5-dione-1: 4-dicarboxylic esters, respectively. The ethylene bridged compound gave $\beta\beta'$-dicarboxy-suberic acid on hydrolysis which was synthesized from ethyl-butane-tetracarboxylate and brom-acetic ester. A number of syntheses including some interesting hydrocarbons likely to possess carcinogenic properties have been effected.

Oxidative degradation of the corresponding bicyclic hydrazones is one of the important methods for synthesizing tricyclic compounds. With a view to studying, if the bicyclic compounds can be synthesized with equal ease from the corresponding monocyclic hydrazones, a systematic study in bridge formation between 1: 4- and 1: 3-carbon atoms of compounds of the cyclohexane series has been undertaken.

Walden Inversion and Asymmetric Synthesis

Mesotartaric acid has been converted into *l*-tartaric acid by the application of Walden inversion process under asymmetric conditions. Additional data in support of Horton's generalisations have been obtained. The influence of the phenyl and carboxyl groups on the course of reaction in Walden inversion has been studied.

Abnormal Optical Rotation

In an effort to synthesize compounds with abnormally high optical rotation, 1: 4-naphthalene-bis-iminobenzylidene-iminocamphor containing 17 double bonds has been synthesized which

shows molecular rotation of 22050° which is the highest of all rotation records so far known.

Cantharidin

Cantharidin has been isolated in 2·3 per cent. yield from *Mylabris pustulata*, a local variety of blister beetles. A number of attempts towards its synthesis by different methods have been made:

Reformatsky Reaction with ethyl bromomalonate and acetone yielded ethyl acetonyl-isopropyl malonate which was successively cyclised to Vörlander's ester and hydrolysed to methone.

Studies in chemical equilibrium in butadiene formation.— Catalytic dehydration of *n*-butyl alcohol over activated alumina at 400° C. gave practically pure *l*-butene, the yield being theoretical. The dehydrogenation equilibrium of butene to butadiene has been studied at the low pressure of 5 mm. to 50 mm. within the temperature range 360–540° C. in a flow system with Al_2O_3–Cr_2O_3 as catalyst. The equilibrium constants at different temperatures and the heat of reaction have been determined

$$CH_3–CH_2–CH = CH_2 \rightleftharpoons CH_2=CH–CH=CH_2+H_2$$

Studies with methone

With a view to studying the chemisrty of alicyclic 1 : 3-diketones, the behaviour of methone towards aldehydes, diazonium chlorides, and anthranilic acids has been studied. Condensation of C-acetyl methone with aromatic aldehydes yielded corresponding flavanones.

β-Aryl-glutaconic acids

An extensive study has been made of the chemistry of β-aryl glutaconic acids.

Miscellaneous

Studies have also been made on (i) cardiac aglucones, (ii) stereochemistry of decalins, (iii) isomeric changes in triazoles and thiobiazoles and (iv) influence of double bond on the stability of heterocyclic systems.

Researches in Applied and Industrial Chemistry

1. *Essential Oils and Fatty Oils*

Chemical examination of a large number of essential oils and fatty oils has been carried out and their possible utilisation studied. The following are some of the oils studied:—Oil from *Cyperus rotundus, Spheranthus indicus, Ocimum canum, Dolichos lablab, Erythrocylon monogynum*, Sandalwood oil, Bapgalore lemon oil, Tobacco seed oil, Indian turpentine oil, Geraniol from Ceylon citronella oil, Eucalyptus oil, *Psoralia corylifolia* oil, *Lansyum annamalayanum* oil, oil from oleo-resin of *Hardwickia pinnata*, and leaf oil of *Atlanta monophylla*.

2. *Glycerine from Soap-lye*

As the result of a request from the Director, Industrial Research Bureau, Delhi, dated 2nd October 1937, enquiring whether it will be possible to undertake research on the recovery of glycerine from soap-lye, in our laboratories, the problem was undertaken for investigation. At the time of receipt of this request there was no factory in India to recover glycerine from soap-lye.

As a result of our laboratory experiments, we put up an experimental pilot plant with a production capacity of 1 cwt. of 67 per cent. glycerine per day, which was later converted into pure glycerine.

3. *Researches on coal tar products*

Coal tar has been distilled in a mild steel still in a furnace (with chimney for the escape of the flue gases), specially constructed for the purpose. Light oil, middle oil, heavy oil and anthracene oil were collected at different ranges of temperature. The *light oil*, *middle oil* and *heavy oil* portions have been distilled using special fractionating columns and the distillates on treatment with acids and alkalies have been separated into neutral, basic and acidic fractions, and details have been worked out for the isolation of the commercially important substances like benzene, toluene, xylene, naphthalene, phenol, cresols, pyridine, etc.

Detailed study of anthracene oil: *isolation of new ingredients.*— The neutral, basic and phenolic portions of anthracene oil have been separated and each portion fractionated with a view to isola-

tion of individual ingredients, either as such or through characteristic derivatives. The neutral portion has been subjected to fractional distillation under reduced pressure at 10° range of temperature when solids separated out. The mother liquors were fractionally distilled at 5° and at 2° ranges and the separated solids from these three series of fractions have been characterized.

Isolation of anthracene, phenanthrene, acenaphthene and carbazole in chemically pure form and in improved yields has been effected from anthracene oil.

In addition to anthracene, phanenthrene, acenaphthene and carbazole, a number of new compounds have been isolated by subjecting the neutral and phenolic portions of anthracene oil to repeated careful fractionation under reduced pressure and by repeated crystallization of the solids separating out of the fractions. Some of the liquid fractions after separation of solids on being kept for a long time in the refrigerator yielded solids which have also been further studied.

4. *Synthetic Drugs*

Chemotherapy of bacterial infections

A. Sulphanilamides

Soon after the discovery and introduction of the sulphanilamide series of drugs for combating bacterial infections, extensive research work was undertaken in these laboratories and a large number of new sulphanilamide derivatives have been synthesized and some of them pharmacologically tested. The following classes of new compounds have been synthesized:

(1) Gold salts of sulphanilamide derivatives; (2) Sulphanilamide derivatives possessing heterocyclic rings; (3) Sulphanilamide compounds possessing selenoheterocyclic rings; (4) Sulphanilamide compounds derived from thianthrene; (5) Sulphanilamide derivatives of open-chain compounds containing nitrogen and sulphur (6) Sulphanilamide of mixed sulphides possessing heterocyclic rings; (7) Anils of sulpha-pyridine and sulpha-thiazoles; (8) Sulphanilamides derived from alkyl isothioureas; (9) Sulphanilamide derivatives of substituted thio-semicarbazides; (10) Some N^4-sulphanilamides; (11) N^4-acyl substituted sulphonamides; (12) Some derivatives of sulphathiazole and sulphapyridine;

(13) N^1-Acyl substituted sulphonamides of the general formula $R.(CO.NH.SO_2.C_6H_4.NHAc)_2$; (14) N^4-Alkylene disulphonamides of the general formula $(CH_2)_n.(NH.C_6H_4.SO_2.NH_2)_2$; (15) N^1-Alkylene disulphonamides of the general formula $(CH_2)_n.(NH.SO_2.C_6H_4.NHAc)_2$; (16) Diphenyl-amine-4: 4'-disulphonamides of the general formula $NH.(C_6H_4.SO_2.NHR)_2$; (17) New sulphanilamide compounds of the general formula $AcNH.C_6H_4.SO_2N=\begin{matrix} S-\!-S \\ | \quad | \\ C \quad C.NRR \\ \diagdown \!\!\!= \diagup \\ N \end{matrix}$ (R and R_1 = alkyl and aryl groups); (18) N^4-substituted disulphanilamido derivatives; (19) *p*-Nitrobenzene-sulphonamides; (20) N-substituted azobenzene-4: 4'-disulphonamides; (21) Schiff's bases of the general formula $(CH_2)_2.(NH.SO_2.C_6H_4.N=CHR)_2$; (22) Azo-compounds of the general formula $(CH_2)_2.(NH.SO_2.C_6H_4.N=NR)_2$; (23) Ethylene-bis-$N^1$-($N^1$-aliphatic-acyl-sulphanilamide)'s of the general formula $(CH_2)_2.(NH.SO_2.C_6H_4.NH.CO.R)_2$; (24) Ethylene-bis-$N^4$-($N^4$-aliphatic-acyl-sulphanilamide)'s of the general formula $(CH_2)_2.[N(COR)C_6H_4.SO_2NH_2]_2$; (25) Sulphanilamides containing groups like –NH.NH–, –NH.CH_2–, –CH_2.NH.CH_2–, –NH.CO.CH_2–NH–, etc.; (26) N^4-Sulphanilamidoaliphatic esters of the general formula $R.NH.C_6H_4.SO_2.NH_2$; (27) Disulphonamides of the general formula $R.NH.SO_2.C_6H_4.SO_2NH.R$.

B. Sulphones

Sulphone drugs.—Compounds of the 4: 4'-diaminodiphenylsulphone group, though not strictly belonging to the sulphanilamide group show typical sulphanilamide activity, their bacteriostatic effect being reversed by *p*-aminobenzoic acid.

It is well known that three derivatives of this compound, *viz.*, the disodium salt of the N: N'-di-dextrose-sulphonate (promin), the diformaldehyde sulphoxylate (diasone) and the diphosphorylated derivatives have shown evident inhibition of the development of experimental tuberculosis in guinea pigs. Promin has also been tried against leprosy and encouraging results have been obtained. Experimental conditions for the preparation of promin and diasone were established.

The above led us to undertake a systematic study of the acyl-, azo-, sulphonyl- and aldehydo-derivatives of 4-nitro-4'-

aminodiphenylsulphone and 4: 4'-diaminodiphenyl-sulphone and a number of compounds have been made.

C. Synthetic antimalarials

Atebrin.—In the field of synthetic antimalarials our studies have been extensive. The conditions for the preparation of atebrin mostly from Indian raw materials through 26 distinct chemical operations, commencing from benzene, alcohol and lime acetate have been established.

Paludrine.—Conditions for the preparation of paludrine starting from indigenous benzene and acetone and passing through the various stages, have been established.

Benzene → Nitrobenzene → Aniline → Acetanilide → *p*-chloracetanilide → *p*-chloraniline $\xrightarrow[\text{diamide}]{\text{dicyan-}}$ chlorophenylazocyanoguanidine → *p*-chlorophenylcyanoguanidine

Acetone $\xrightarrow[\text{Ni catalyst}]{NH_3 + H_2}$ Isopropylamine → Paludrine.

p-Chloraniline has also been made *via p*-chloronitrobenzene.

Synthesis of new potential antimalarials.—A large number of new compounds of the acridine, quinoline, benzoquinoline and pyridine series has been synthesized as possible antimalarials.

Considerable attention has also been directed to the synthesis of a variety of new biguanide derivatives some of them being sulphabiguanides, N^1-(8-quinolyl) and (8-chloro-5-quinolyl)-N^5-phenyl-biguanides, biguanido-arsenicals and substituted guanidines. The pharmacological results of some of the sulpha-biguanides have been encouraging.

D. Miscellaneous synthetic drugs

Considerable amount of work has been done on the synthesis of (1) organo-arsenicals, -antimonials and -mercurials, (2) new method of synthesis of phenacetin, (3) therapeutic agents from quininic acid, (4) anæsthetics and local anæsthetics, (5) coramine and allied compounds, (6) sympathomimetic drugs, (7) barbiturates, (8) analgesics, and (9) penicillamine.

Utilisation of the carene-content of the Indian turpentine oil.—Carenes (Δ^3 and Δ^4) occur in Indian turpentine oil to the extent

of 50–60 per cent. The first step towards the utilisation of carene content of turpentine oil for the preparation of thymol and menthol is its conversion to *p*-cymene. Researches in our laboratories have made available a ready source of *p*-cymene by conversion of the carene content of the Indian turpentine oil by catalytic dehydrogenation. The cymene thus prepared has been converted, passing through six operations, into thymol and menthol on laboratory scale, the yield of thymol being 22 per cent. on *p*-cymene.

Dyes and dye-intermediates.—Experimental conditions for the preparation of a number of important dye-intermediates and dyestuffs have been established.

Production of p-*nitrophenyl-azo-β-naphthylamine.*—At the request of the Supply Department, Government of India, 2,000 lbs. of this dye were prepared and supplied. This necessitated the preparation of (i) 1,000 lb. of β-naphthylamine from β-naphthol in an autoclave devised, designed and constructed by us, and (ii) ammonium sulphite by the combination of ammonia and sulphur dioxide. For the preparation of the latter a special equipment had to be devised.

Preparation Section.—Since 1930 a Preparation Section has been added to the Department where commercially useful as also research and fine chemicals are prepared, some on a semi-large scale basis. During the last 18 years about 500 organic chemicals have been prepared and supplied for departmental use.

Industrial researches sponsored by the Council of Scientific and Industrial Research

1. *Organo-arsenical drugs.*—The method of preparation of the following organo-arsenical drugs: (i) atoxyl, (ii) carbarsone, (iii) sulpharsphenamine, (iv) neo-salvarsan, and (v) stovarsol (starting with materials available in India), have been successfully established. The toxicity and therapeutic potency of sulpharsphenamine was tested pharmacologically and found to be upto the standard.

2. *Synthetic Adrenaline.*—Method for the preparation and optical resolution of synthetic adrenaline (starting from catechol)

has been established. Experiments have been conducted for the preparation of catechol by various methods, *viz.*, (i) and (ii) from phenol *via* *o*-chlorophenol and *o*-sulphonic acid, (iii) by the oxidation of phenol by various oxidising agents, (iv) oxidation of benzene, (v) from catechu, (vi) from wood-tar guiacol. The methods (i) and (iii) have been established successfully.

3. *New antimalarials*: *Synthesis of compounds isomeric with paludrine.*—Work on this scheme was started from January 1948. A new method has been established for the synthesis of compounds allied to paludrine starting from both meta and para isomers of chloro-, bromo- and iodo-phenyl-dithiobiurets prepared for the first time from the corresponding chloro-, bromo- and iodo-anilines and xanthane hydride. 2-Alkylthiol, 4-alkylthiol, and 2. 4-dialkylthiol derivatives of the dithiobiurets have been made. The mono-S-alkyl group (in position 2 or 4) or the di-S-alkyl groups (in positions 2 and 4) have been converted into alkyl-amino groups (–NHR) by the action of alkyl-amines resulting in the formation of three different and interesting series of compounds likely to possess antimalarial properties. With *p*-chloraniline the following three types of compounds have been made; the last one (R = H, R′= isopropyl) being not identical as expected, but isomeric with paludrine:

(1) $Cl.C_6H_4.N = C(NHR).NH.CS.NH_2$
(2) $Cl.C_6H_4.NH.CS.N = C(NHR).NH_2$
(3) $Cl.C_6H_4.N = C(NHR).N = C(NHR').NH_2$

Biguanide derivatives of aromatic and substituted aromatic compounds have been made from the corresponding amines through the corresponding (i) thioureas, and (ii) cyanamides.

Biguanido-phenyl arsonic acids.—With a view to studying the pharmacological properties of organo-arsenicals having certain essential structural features of the reported antimalarial drug paludrine, several biguanido aryl-arsenicals have now been synthesized by reacting cyanoguanidine and aryl cyanoguanidine with excess of *p*-arsanilic acid hydrochloride in dilute alcoholic medium. N_5-R-(N′)-*p*-biguanido-phenyl-arsonic acids of the general formula R-NH-C (:NH)-NH-C (:NH)-NH-C_6H_4-AsO $(OH)_2$ (R = H, Ph, tolyl, anisyl, *p*-chlorophenyl, *p*-acetaminophenyl, etc.), have been made.

Bis-biguanido-arsenobenzenes.—It is now widely accepted from the pharmacological data that the arsenic compound of the pentavalent type becomes therapeutically active only on reduction in the body to the tervalent state. In view of these observations, some compounds of the above types have been reduced with hypo-phosphorus acid and potassium iodide to the corresponding arseno-derivative of the general formula [R-NH-C(:NH)-NH-C(:NH)-NH.C_6H_4.As=]$_2$ [R = H, C_6H_5-, *p*-Cl.C_6H_4-, *p*-CH_3.C_6H_4-, *p*-CH_3.C_6N_4-], which are fairly stable and practically insoluble in water. The yellow arseno-compounds possess no definite melting points, their hydrochloride melting with decomposition. Eight substituted bisguanidines have been prepared starting from *m*- and *p*-phenylenediamine.

4. *Novocaine.*—Novocaine has been prepared along with the intermediate chemicals required for its preparation, passing through 10 distinct chemical operations.

The three important starting materials for the preparation of novocaine are *p*-nitrotoluene, diethylamine and ethylene chlorohydrine. Equipments for pilot-plant experiments for the preparation of *p*-nitrotoluene and diethylamine (from diethylaniline) have been constructed. With the first equipment, 22.5 lbs. of toluene has been nitrated in one operation yielding 31 lbs. of nitro-toluenes from which by fractional distillation 11.5 lbs. of *p*-nitro-toluene has been made in one operation. With the second equipment, pure diethylamine (about 5 lbs.) has been prepared per day.

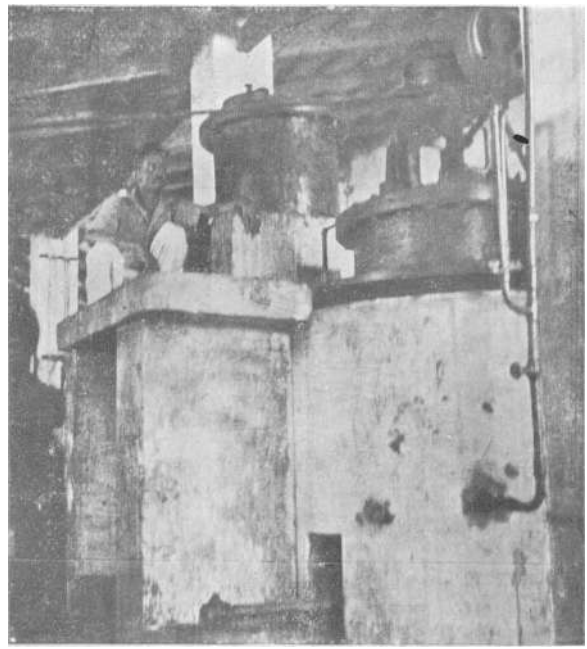
The sample of Novocaine prepared has been tested pharmacologically and found to be upto B.P. standard.

5. *Nitrobenzene, Aniline and Dimethylaniline*: *First stage.*—Series of experiments had to be performed on laboratory scale to find out the best working methods for the preparation of nitrobenzene, aniline and dimethylaniline.

Second stage.—This was followed by small scale pilot-plant experiments on nitration and reduction (with cast iron vessel of 20 gallons capacity) and methylation under pressure in an autoclave of about 3 gallons capacity.

Third stage.—A cast iron nitrator (capacity 100 gals.) and a reducer (capacity 100 gals.) were designed and fabricated locally with all their accessories, and put into operation successfully. The nitra-

PLATE III



NITRATION PLANT

Showing Mixed acid vessel, Nitrating pan, Discharge valve Bevel gear Inlet pipe for cooling jacket, and Cooling jacket.

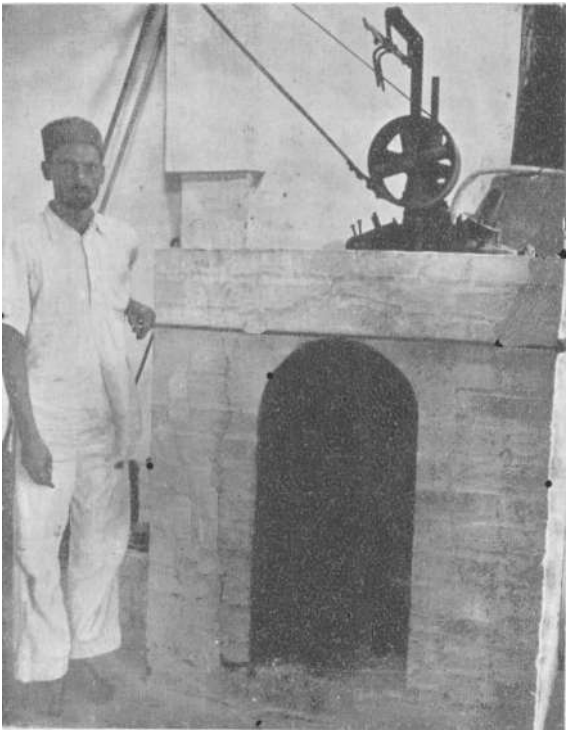
ANILINE PLANT

Showing Reducing kettle, Bevel gears, Charging cone, Inlet for steam, Discharge valve, Goose neck, Condenser (partly visible behind the pillar), Settling tank, Steam trap.

PLATE IV

SULPHONATION PLANT

Showing Sulphonation pan with heating arrangements by ordinary and super-heated steam (not visible) and heated oil, with stirring gear, belt, pulley: Furnace for heating oil; Condenser, Discharge valve.



ALKALI FUSION PLANT FOR PHENOL

Showing Fusion pan (only top visible) with stirring gear, etc., with side gears and belt arrangement, Furnace

tor gives 240 lbs. of nitrobenzene and the reducer about 160 lbs. of aniline per shift of 10 hours, respectively. By running the nitrator and the reducer each twice every day, 4 tons of nitrobenzene and 2½ tons of aniline (from 3½ tons of nitrobenzene) can be produced per month. In an improvised autoclave designed and constructed here and with heating and shaking arrangements, it has been possible to convert 50 lbs. of aniline into 62 lbs. of dimethylaniline per day.

Fourth stage.—With the object of testing the durability and satisfactory working of the *nitrator* and the *reducer plants* about 20,000 lbs. of nitrobenzene have been prepared and converted to 13,000 lbs. of aniline.

6. *Musk xylol, musk ketone and musk ambrette.*—Detailed methods for the preparation of (i) musk xylol, musk ketone and musk ambrette, as also the intermediate chemicals (*e.g.*, pure *m*-xylene from crude xylene, isobutyl chloride, analydrous aluminium chloride, pseudobutyl-*m*-xylene, for the production of musk xylol); (ii) pseudobutyl-xylyl-methyl ketone for musk ketone; and (iii) *m*-cresol-methyl-ether (from cresylic acid commercial), tert. butyl-*m*-cresol-methyl ether for musk ambrette, were established. Pilot-plant experiments were conducted for the nitration of pseudo-butyl-*m*-xylene and 6 lbs. of pure musk xylene were obtained in one experiment.

7. *Sulphur compounds from coal.*—Assam coal has been found to contain 4·5 per cent. of sulphur. Coal containing high percentage of sulphur is not suitable for metallurgical operations. With a view to finding out proper solvents for sulphur present in coal, experiments have been conducted using coal-tar fractions and low boiling organic solvents like acetone. Work has also been started to elucidate the chemical nature of the sulphur compounds present in coal about which little is known at present.

Assam coal (S, 4·55%) was extracted with various solvents, under varying conditions of temperature and pressure. The most encouraging results were obtained with acetone as solvent, and a few pilot-plant extractions of coal have been conducted with acetone in an extractor specially constructed for the purpose. Free sulphur was also found to be present to the extent of approximately 0·05 per cent.

Detailed chemical examination of the basic, acidic and neutral portions of the acetone extract of coal and also of extracts with other solvents on Assam coal is in progress. The neutral portion comprising the major fraction (*viz.*, 75%) was fractionally distilled under reduced pressure and the fractions are under study.

8. *Phenol.*—After having successfully carried out laboratory-scale experiments for the preparation of phenol from benzene, through sodium benzene sulphonate *by the entrainer process*, a mild steel sulphonation unit has been designed and fabricated, and the results of sulphonation on pilot-plant basis have been found to be quite in agreement with that obtained in laboratory-scale experiments. A fusion unit for treatment of about 10 lbs. of sodium benzene sulphonate has been designed.

β-Naphthol and phenol.—Prior to the sanction of the Phenol Scheme by the C.S.I.R., number of experiments were conducted on the sulphonation of naphthalene and benzene on pilot plant basis; 90 lbs. of sodium β-naphthalene sulphonate has been prepared in one charge by sulphonating 50 lbs. of naphthalene; 90 lbs. of sodium β-naphthalene sulphonate on alkali fusion have yielded 42 lbs. of β-naphthol in one operation.

Benzene (25 lbs.) on sulphonation furnished 52 lbs. of sodium benzene sulphonate in one operation, which furnished 23 lbs. of crude phenol on alkali fusion.

9. *Preparation of Coumarin.*—Various methods for the preparation of coumarin have been tried starting from salicylaldehyde, *viz.*, (1) Perkin's method using acetic anhydride and sodium acetate; (2) Stuart's method using malonic acid with glacial acetic acid and aniline hydrochloride as catalysts; (3) Cyanacetic acid; and the last one has been found to furnish the best yield. Coumarin carboxylic acid obtained by the third method can be easily decarboxylated to coumarin, the yield being almost quantitative.

The preparation of coumarin cannot be regarded as successful unless the method of preparation of the starting material, *viz.*, salicylaldehyde is established on a commercial basis. With that end in view number of experiments have been tried. But it is felt that one experiment remains yet to be performed, *viz.*, electrolytic reduction of salicylic acid.

List of Exhibits

Charts, photographs, samples and/or experiments are exhibited under each of the following items:—

1. Coal tar products.
2. Wood tar products.
3. Alcohol and chemicals derived from it.
4. Synthetic drugs and intermediates: (i) sulphanilamides, (ii) antimalarials, (iii) local anæsthetics, (iv) organo-arsenicals, (v) barbiturates, (vi) sympathomimetics.
5. Ammonolysis: Preparation of isopropylamine (essential starting material for paludrine) from acetone, ammonia, hydrogen and Raney's nickel as catalyst.
6. Extraction of colouring matter from natural products.
7. Synthetic dyestuffs and intermediates.
8. Indian essential oils.
9. Isolation of essential oils: (*a*) steam distillation, (*b*) expression, (*c*) enfleurage, (*d*) solvent extraction.
10. Santalol and santalyl acetate prepared from Mysore sandalwood oil.
11. Utilisation of Mysore cardamom.
12. Turpentine oil from oleo-resin.
13. Products of destructive distillation of rosin.
14. Aromatic chemicals : musk xylol, musk ketone, musk ambrette, coumarin, etc.
15. Oils and fats.
16. Glycerine from soap-lye; purification of crude glycerine by vacuum distillation with super-heated steam.
17. Chromatography.
18. High vacuum distillation (Tower's Apparatus).
19. Cantharidin from a local variety of Blister beetles.
20. Chemiluminiscence.
21. Nitration of toluene in 25-gallon nitrator.
22. Separation of *p*-nitrotoluene from a mixture of *ortho*- and *para*-isomers by fractionation under reduced pressure.
23. Purification of crude *p*-nitrotoluene by steam distillation.
24. Pilot-plant preparation of ether.
25. Sulphur compounds from coal.
26. Chemicals with different smell, taste and colour

5. PHARMACOLOGY

The scheme for the establishment of a small pharmacological unit having taken a final shape with allocation or funds in January 1941, work was begun by the middle of July 1941, with a small staff of one pharmacologist and laboratory assistant in the unit. This unit was entrusted with very highly technical and responsible work which has gradually progressed. A research assistant in bacteriology was added to the staff in August 1942. The unit is maintaining a large number of bacterial strains which are generally required for assay work. The Bacteriologist has been actively collaborating with the Pharmacologist in all the activities of the Pharmacological Laboratory. Besides, the bacteriologist is engaged in the chemotherapeutic investigation of the various drugs prepared by the Organic Chemistry and Biochemistry Departments.

Activities of the Laboratory

The Laboratory has attempted to provide itself with every possible means for routine experimental work and for undertaking research problems pertaining directly or indirectly to drug standardization and drug analysis. It has also actively collaborated with various activities of the Organic Chemistry and Biochemistry Departments.

(i) *Analysis of the quality and potency of the drugs prepared by the Organic Chemistry Department.*

- (*a*) Hypnotics (barbituric acid derivatives)
- (*b*) Sulphonamide groups of drugs,
- (*c*) Organic arsenicals, *e.g.*, carbasone, stovarsol, neoarsphenamine, sulpharsphenamine, maparside, etc.,
- (*d*) Antimalarials,
- (*e*) Synthetic adrenalin,
- (*f*) Local anæsthetic,
- (*g*) Antiseptics and disinfectants.

(ii) *Analysis of quality and potency of drugs prepared by the Biochemistry Department.*

- (*a*) Insulin,
- (*b*) Pituitary extract (post. lobe)

(*c*) Adrenalin,
(*d*) Thyroid powder,
(*e*) Peptone.

Preparation of stable "Standard" for drugs

Owing to the comparatively limited supply of the International Standard from London and elsewhere during the war, request was made by the Biochemical Standardization Laboratory, Calcutta, if this laboratory could actively co-operate to prepare stable subsidiary standard for pituitary (posterior lobe). Accordingly, this unit prepared under strictly controlled conditions pituitary powder (posterior lobe) and standardised it carefully in terms of the International Standard. The powder compares very favourably with the International Standard and it has been sealed in ampoules and a quantity sent to the Director, Biochemical Standardisation Laboratory.

Research and Investigation

This Laboratory has a well-planned system of close co-operation and co-ordination of work with the various Departments at the Institute. The unit has carried on investigations of diverse nature in collaboration with the Biochemistry and Organic Chemistry Laboratories.

In addition to the routine activities of the Laboratory, a good deal of interest in the research problem has been consistently maintained:

(*a*) Research on standardisation problem.

(*b*) Side by side with investigations on purely standardization problems, as detailed above, the Laboratory has also maintained a fair amount of interest in other allied problems of certain drugs, with special reference to their mode of action.

Investigations have been carried on the Oestrogenic and Galactogogue Therapy of the Indian Cress oil (*Lepidium satirum* Linn.) and the results so far obtained have been published.

(*c*) Researches on immunity and nutrition: The role of different dietetic factors in conferring resistance to infection has been investigated.

(*d*) Studies on penicillin and other allied drugs, the methods of extraction and preparation of stable compounds and methods of assay have been done.

(*e*) Investigation on the phosphorus partition of brain proteins of mammals have yielded results of great interest.

(*f*) Routine examinations as regards the bacteriostatic activity of different derivatives of sulphonamide have been carried on in collaboration with the Organic Chemistry laboratory.

(*g*) Chemotherapy of some organic mercuric compound and their activity against *Staphylococcus amens* has been investigated.

(*h*) The chemotherapeutic investigation of various arsenic and antimony compounds on lizard filaria.

(*i*) Chemotherapy of some acridine derivatives on fowl malaria has been carried on. Antimalarial drugs of the paludrine type and some with sulpha-combination are being tested for their antimalarial properties on fowl malaria.

(*j*) In collaboration with the Biochemistry laboratory the investigation on the antibiotic properties of various indigenous drugs and the metabolic products of some moulds are being continued.

Exhibits.—Some interesting physiological experiments—working of the mammalian heart, capillary circulation, respiration, etc.—will be exhibited.

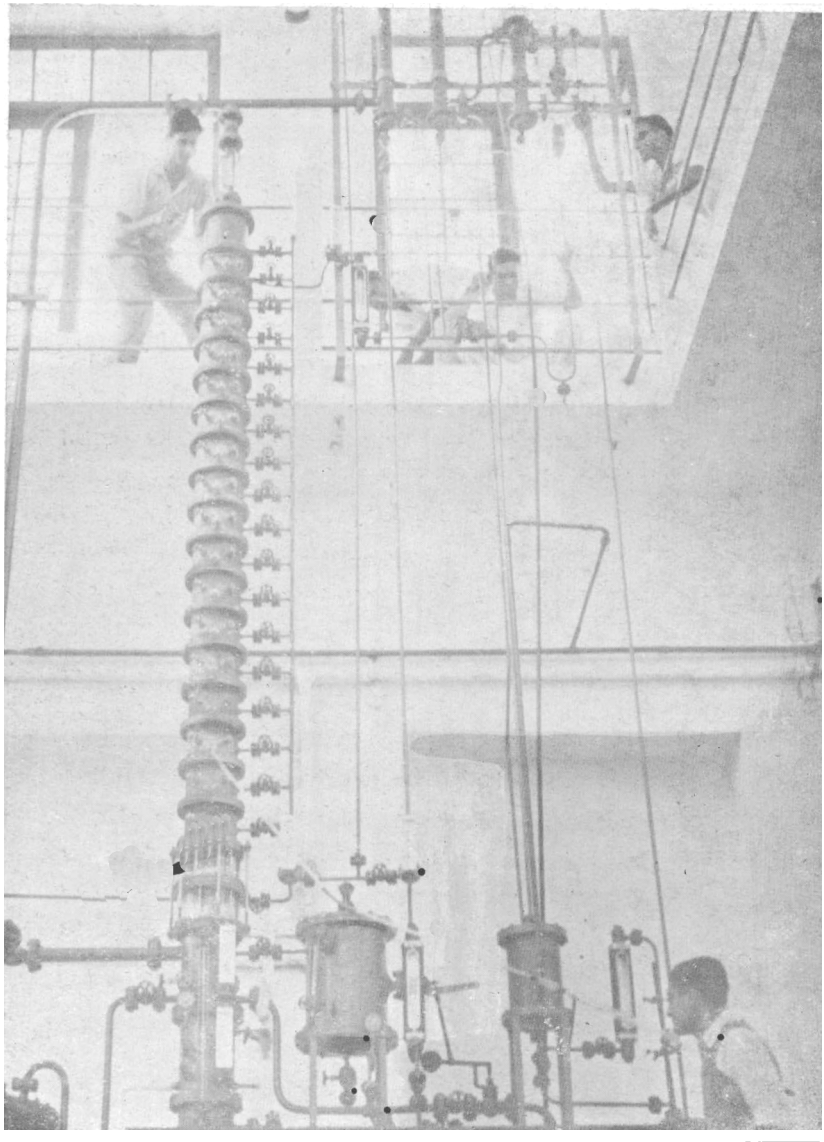
6. CHEMICAL ENGINEERING

The phenomenal growth of chemical industries over the span of the two world wars has inevitably led to the recognition of chemical engineering as a study of major importance in recent years; while the fixation of atmospheric nitrogen and the manufacture of nitric acid from air and water as the raw materials for munitions production was a great achievement during the first world war, the production of synthetic rubber, synthetic petrol and plastics on a large scale were notable achievements during the second world war. These successes were largely attributable to the advances made in the study of chemical engineering, parti-

PLATE V

Chemical Engineering building and laboratories

PLATE VI



Bubble Cap Distillation Column

cularly in America and Germany. The Indian Institute of Science, Bangalore, is one of the pioneer institutions in India, in which an advanced course of Chemical Engineering has been established, providing not only up-to-date instruction to post-graduate students but also practical training and research facilities on the subject. At the same time a close link is also established with study of operations in chemical industry. The Department is housed in a new three-storeyed building with a floor area of 14,000 sq. ft. and its laboratories are equipped on the most modern lines. The minimum qualification for admission of students to the Chemical Engineering Diploma course is M.Sc. (chemistry) or B.Sc. (Hons.) in chemistry with physics and mathematics as subsidiary subjects on an average. 15 Students are admitted every year representing different universities in India. It is gratifying to note that all the students, who have successfully completed the Diploma Course have hitherto found suitable employments in the country. The duration of the Chemical Engineering Course including teaching and research is 3 years.

The Chemical Engineering Laboratories will repay a visit both to the general technician and the expert scientist. The main Plant Laboratory has been equipped for carrying out experiments on most of the unit operations in chemical industries on a Pilot Plant scale. Many of the equipments have been fabricated in the Department and a few specialized equipments purchased from abroad.

The engineering of the problems commonly met with in chemical processes is demonstrated by special equipments as follows:—

Flow of fluid.—Apparatus for determining friction loss in pipes and fittings, friction loss for flow through granular solids, pitot tube, rotameters, Weirs and other meters.

Flow of heat.—Heat exchangers, Apparatus for testing efficiency of pipe laggings, etc.

Evaporation.—Film evaporator, steam ejector, calorimeter, kettles.

Distillation.—Packed column, bubble cap column (obtained from the U.S.A.), sieve plate column.

Filtration.—Filter presses, Vacuum leaf filter.

Crushing and grinding.—Jaw crusher, ball mills, edge runners, rod mill, disintegrator.

Ore dressing.—(Obtained from the U.S.A.) Vibrating screen, mineral jig, electromagnetic separator, rock and specimen cutter, continuous thickener with sand pumps, classifier, Wilfley table, continuous flotation machine, sieve shaker with standard sieves.

Gas absorption.—Wetted wall and packed gas absorption columns.

Mixing.—Various types of mixers, colloid mill.

Drying.—Rotary drier, compartment and vacuum drier, electric muffle furnace.

Solvent extraction.—Packed and plate columns for liquid-liquid extraction.

Pilot plants.—Pilot plants for hydrogenation of vegetable oils, and for catalytic oxidation of methanol to formaldehyde.

Miscellaneous equipments.—Autoclave for high pressure work, refrigerator, different types of pumps and compressors, etc.

A few specialised equipments, *viz.*, Oliver Rotary Continuous Filter, Sweetland Filter, Double Drum Vacuum Dryer are expected to arrive shortly from abroad.

Research

In spite of the fact that the laboratories have been equipped very recently, a number of investigations on chemical engineering problems have been carried out and the following publications may be mentioned:—

(1) Solvent extraction in spray column.

(2) Liquid-liquid extraction in packed column.

(3) Flooding and pressure drop in packed column for liquid-liquid extraction.

(4) Performance of sieve plate fractionating column.

(5) Method for designing packed columns.

The following problems are at present under investigation. Economic extraction of alumina from Kashmir bauxite having

high silica content, production of active carbon and chemical engineering problems on distillation and solvent extraction.

The Department is also carrying out investigations on the following research schemes under the auspices of the Council of Scientific and Industrial Research:—

(1) Industrial catalysis,

(2) Synthetic methanol,

(3) Manufacture of beryllium and alloys.

A brief review of the work done on the above schemes is given below.

I. Scheme on industrial catalysis

(*A*) *Fischer-Tropsch process for production of synthetic liquid fuel.*—The Fischer-Tropsch Process discovered in Germany in 1925, came into prominence during the second World War when Germany started the production of Motor Fuel from Coal on the basis of this process. Other products of the German Fischer-Tropsch plants profitably used were as follows:—The soft wax converted into fatty acids by catalytic oxidation in air. About half the acids thus produced were of the type required for soap manufacture. The higher acids were used in the manufacture of lubricants and water-proof camouflaged paints. The hard wax was used for the manufacture of polishes, electrical insulating materials, water-proof paper and other articles.

Cobalt was the most favoured catalyst and results with iron catalysts were not encouraging in Germany.

The aim of the investigations in this laboratory is to substitute a cheap iron satalyst for cobalt and to secure high yield of hydrocarbons. A promising iron catalyst has been found out and the results are very encouraging; nearly 65–70% conversion (*Per Single Pass*) has already been secured. The yield of wax and heavy oils is found to be high. Further work is in progress.

(*B*) *Production of hydrogen by Steam Iron Process using Indian iron ores.*—The Steam iron process is a very widely used method for manufacture of hydrogen. But till now very little investigation has been done about the suitability of Indian iron ores for this process. In the present investigation different Indian ores are being tried.

An ore from Badampahar in Mayurbhang State has proved to be a suitable variety as the percentage of sulphur and silica are low; moreover, it is quite porous and robust after calcination. From our investigation it was clear that the ore under investigation was quite satisfactory so far as its activity was concerned. The only disadvantage that was observed in the course of our experiments was that the active life of the mass was rather short. Further investigation is in progress.

(*C*) *Synthesis of ammonia.*—Nitrogen and hydrogen mixture is prepared by burning hydrogen in a limited supply of air. The mixture after necessary purification is passed over iron catalysts.

Fluidized catalysts will be tried for ammonia synthesis. Apparatus has been set up and investigations are in progress.

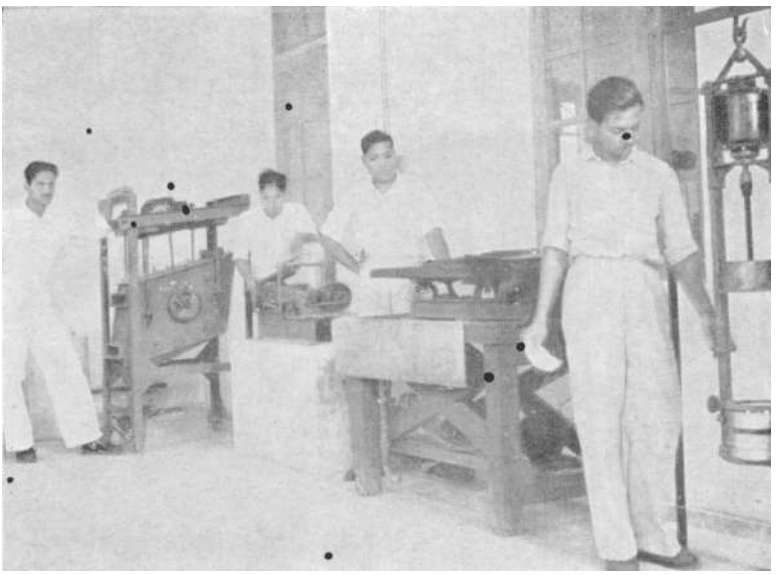
II. Scheme on synthesis of methyl alcohol from water gas

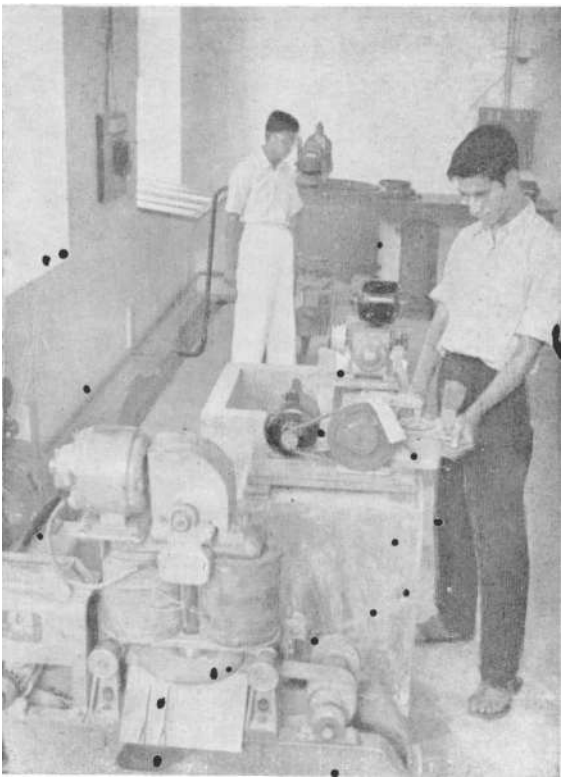
Experiments have been conducted on the preparation of water gas from coke with steam and oxygen. Raw gas has also been purified for catalytic reactions and supplied after compression to 120 atmospheres.

Methanol synthesis has been conducted at 100 atmosphere pressures with different catalysts, containing copper as main components with various promoters under different conditions and interesting results have been obtained. The best catalyst gave 60% conversion and crude product contained 90% methyl alcohol, rest being mainly water. Further work in this line is in progress.

III. Scheme on manufacture of beryllium and its alloys

Beryllium came into prominence only during this war as "the wonder metal" which in the smallest quantities of addition fortifies the parent metal or alloy to withstand and resist fatigue under high strains and stresses in engines and other vital parts of machines of great importance. This metal surprisingly assumed almost strategic importance overnight during the war and attained top priority as a key material. Beryllium forms an alloy with copper which is extremely useful for construction of some delicate instruments in aircraft and electrical industries. It is also pre-





Two views of the Ore Dressing Laboratory

sumed that metallic beryllium is used at some stage in the development of atomic bomb.

Beryllium is usually obtained from the mineral beryl. India is the only country which practically holds monopoly of good variety of beryl and the Government of India have now placed an embargo on the export of the mineral abroad. The present investigation has been undertaken in order to explore the possibility of processing and utilising the mineral. So far, the results obtained have been highly interesting. We have been able to produce beryllium oxide of high purity from Indian beryl and beryllium-copper alloys containing 2% and 4% beryllium. Pilot plant experiments are now under progress for manufacture of the oxide from beryl and preparations are afoot for producing the metal and its alloys in larger quantities.

Given below are the details of the exhibits in this Department.

1. Extraction of gold from the ores in the region of Kolar Gold Fields and Bellara gold mines.
2. Extraction of copper from Indian copper ore.
3. Manufacture of formaldehyde from methanol.
4. Manufacture of absolute alcohol from dilute solutions.
5. Separation of benzene and toluene.

BIOCHEMISTRY

The Department of Applied Chemistry was one of the Departments with which the Institute started its career in 1911 and began even then with several investigations of a biochemical character such as the refining of country tallow, deodorisation of gingelly oils, the recovery of citric acid and essential oils from limes and lemons. Work on perfumes and essential oils was also taken up in this Department till it was transferred later on to the Organic Chemistry Section, chiefly due to the recognition or the importance and magnitude of the problems of biochemistry and bacteriology requiring study in the country.

The outstanding work done under essential oils related to the distillation from sandal wood and it is a tribute to the completeness and value of the investigation at the Institute that the early work resulted in the establishment on firm foundation of the largest sandal wood oil distillation unit in the World in Mysore State. Other essential oil studies related to (i) geranium, (ii) *Hardwickia pinnata*, etc., (iii) lemon grass. Investigations on the extraction and properties of cardamom oil from cardamom, a raw material of great economic value, are at present under progress for the Mysore Government.

A collection of these studies and of the samples of several products is exhibited.

A very early and most important activity which received the attention of Dr. Gilbert J. Fowler, then Head of the Department, was the investigation into and development of a scheme for the establishment of an Acetone Factory, the necessity for which had become very clear during the first World War. The process successfully established by Dr. Weizmann consisted in the fermentation of starchy material by means of a specially cultivated bacillus, yielding as chief products acetone and butyl alcohol. Dr. Fowler was successful in bringing out an initial store of certain types of cultures in good condition from Dr. Weizmann. A pilot plant was first set up in the Department, and after some years of very strenuous work on the part of the biochemical

staff assisted by Government engineers, a factory was constructed at Nasik Road and large-scale production was carried on successfully for a number of years. Later on, the factory was sold to the Bombay Government which converted it into a distillery which is still in operation with one of the original Bangalore students in scientific control.

Another important investigation in the early stages of the Department was a scheme for the production of power alcohol and alcohol for other purposes from the *mahua* flower as raw material which grows very extensively in Hyderabad State. A scheme was developed and given over to the Government of Hyderabad which successfully exploited the same.

Besides *mahua* as a source of alcohol, prolonged trials were made by the Burma Oil Company of a process for obtaining alcohol by the fermentation of rice straw, special bacteria and yeasts being employed.

The studies in fermentation technology and science have continuously been expanded starting from these early ones and at the present time, the Institute possesses in the Fermentation Section a most valuable collection of type cultures for bacteriological work.

Recent investigations of an extremely important character, both from the scientific and economic points of view, centre round microbiological assay of vitamins and nutritional studies and the fermentation activities of certain types of bacterial cultures. A comprehensive display of work in these lines is exhibited.

Perhaps the most important activity of the Department in later years was concerned with the scientific control of water supply, and sewage and refuse disposal in all its aspects including its relation to agriculture. In 1922 an activated sludge plant was designed and set up at the Institute capable of dealing with the sewage from 400 people. This installation has enabled very important fundamental research to be done on the biochemistry of the activated sludge process which has resulted in greatly improved modifications in the biological theory of the process.

The work done in this laboratory on the role of protozoa in the aerobic purification of sewage showed for the first time

the fundamental importance of certain forms of protozoa, more especially the *Vorticellids*, in the purification process. The flocculation and oxidation of sewage are largely due to the protozoal activity.

Cause of sewage sickness of soil:

The fundamental cause of sewage-sickness is inadequate aeration which is brought about by the alteration in the mechanical structure of the soil in course of time. Under conditions of insufficient air supply, anaerobic decomposition of sewage tends to take place; gases such as hydrogen sulphide are formed; the rate of percolotion of sewage is considerably decreased; and the quality of the soil effluent is also adversely affected. The conditions in turn affect plant growth and crop yields.

Calcium in different forms, particularly burnt lime at the rate of 1—2 tons per acre has been found useful in restoring the sick soil to the healthy aerobic state. Application of lime leads to quicker drainage, increased air-space, rapid oxidation of organic matter and increased availability of phosphorus.

Nature and extent of infection carried by sewage-grown crops:

The putrefactive and pathogenic organisms in sewage do not penetrate into the sewage-grown crops, although they are invariably present on the surface. They are present in high concentration on crops, such as cabbage and lettuce which grow very near to the soil surface. They are introduced partly through mechanical splashing of sewage and partly through blowing of dust on dry days. They are largely removed through washing but they are never completely eliminated even after ordinary cooking. In the case of vegetables like letttice which are eaten raw, there is always a certain amount of danger of these organisms being taken along with the vegetables.

Studies on the response of crops to sewage irrigation

Almost all crops have been found to respond well to sewage irrigation if the amount of air supply in the soil is satisfactory.

Considered from the hygienic and economic points of view, the crops most suited to sewage irrigation are fodder and industrial crops, like sugarcane. In the case of sugarcane raised

on land irrigated with sewage for a number of years, it was observed that the juice contained appreciable amounts of salts. The salt content of juice was found to affect adversely the setting of *gul*, but it did not interfere with the preparation of white sugar.

Studies on soils more suited to sewage irrigation

Soils containing less than about 25% of clay are generally suited to land treatment of sewage and crop production.

Sewage irrigation need be confined to the early stages of crop growth. The trend of evidence would show that the response of crops depends upon their nutrition in the early stages of growth and that heavy application of sewage after the commencement of flowering is not beneficial to plants.

Studies on the dilution of sewage for application:

The various aspects of dilution of sewage as a measure of more economic utilisation of its fertilising ingredients have been studied. Where irrigation water from an external source (tanks or rivers) is not available the possibilities of using (*a*) the land-filtered sewage effluent, (*b*) sub-soil water from sewage farms, and (*c*) certain trade effluents (*e.g.*, textile mill effluent at Ahmedabad) after suitable pre-treatment have been studied.

After a visit to Rothamsted during his period of leave in 1921 Dr. Fowler returned with great interest in the production of compost after becoming acquainted with the developments at Rothamsted of what was then known as the ADCO Process. Since then the subject has become one of the leading manurial activities of India and many students of the Biochemical Department have taken important parts in the work throughout the country. Other students have held, or are still holding, important positions in connection with new water purification works, their qualifications being based on the training they have had in the Department of Biochemistry.

A systematic study of the various phases of transformations during the initial fermentation and the subsequent decomposition and oxidation of the materials in the compost heap was made and the conditions for actual field operations under different types

of soil and climatic conditions were standardised. The outstanding result of these researches is the production of compost on a country-wide scale in India to-day under the general supervision of the Compost Development Officer under the Ministry of Agriculture, Government of India.

Other activities having a great influence on the development of Indian industries are the many researches which have been published by several workers of the Department regarding the natural history and biochemistry of the lac insect and its bearing on the practical carrying out of the lac indusrty.

The Institute became the recognised centre for work in this subject and the fact that the entire staff of the Lac Research Institute at Ranchi was almost entirely drawn from among the workers from this Institute bears testimony to this fact.

Among the researches completed may be mentioned, the nutritional requirements of the lac insect (the effect of season and host on the yield and quality of lac), the rate of secretion of lac by insects at different stages of its life-cycle, the study of parasites and predators, the essential constituents of different types of seed lac derived from different hosts and different races of lac insects, the dielectric strength of different types of seed lac, the mechanism of the formation of urea-lac complexes and the optical activity of lac.

Extensive researches on the physical and chemical problems of lac resin were carried out for many years resulting in information of great value to the industry being obtained.

Among fibre industries may be particularly mentioned the coir industry where very careful experimental work was made and published by Dr. Marsden which has drawn considerable attention in technical literature.

The large subject of the relation between bacteria and the seeds in which they are found to reside, either characteristically or incidentally, has its bearing on many industries besides coir and mention may be made of the interesting work done in the Department on the bacteriology of the indigo dye vat and on the bacteria associated with rice.

With a view to further expanding the activities of the Department on a large scale Dr. R. V. Norris in 1929 equipped the

Department with equipment and accessories for micro-chemical analysis. The Department was the first of its kind in India to develop the methods of analysis, then lately developed in Vienna Investigations of a biochemical nature in agricultural problems were then taken up in the Department. Extensive grounds and a pot culture house were added to the Department. Sewage farms were extended and researches on sewage farming developed. One main bacteriological laboratory was expanded with additional equipment and a cold storage room for storing perishable biological products, and an animal house was added for nutrition and physiological studies. Studies on disinfection and sterilization and the germicidal properties of Indian essential oils were made. Studies on soil actinomyces occurring in India and special problems like the biological oxidation of sulphur for reclamation of alkali soils under continued irrigation were also taken up.

Enzymology which is a fundamental branch of biochemistry constitutes one of the specialised research activities of the Department. The role of enzymes in plant and animal metabolism and their application in industries such as food technology, pharmaceutieals, and textiles has been investigated. Various methods have been developed for the purification of enzymes and the study of their reactions. The application of enzymes in the study of the constitution of complex biological substances such as starch, and proteins has been investigated. The application of enzymes in the manufacture of predigested foods has been investigated and a new process has been developed for the manufacture of predigested protein foods from oilseed cakes and is being successfully exploited by a well-known manufacturing firm in Madras. Researches carried out in this line have been on the rôle of enzymes in blood coagulation, synthesis of starch in plants, in phosphorus metabolism in relation to the physiological rôle of vitamins, and results of far-reaching importance have been obtained. Dr. V. Subrahmanyan not only continued the researches and investigations that had been established in the Department, but also sponsored the undertaking of a number of research schemes in the Department pertaining to special problems referred by the Indian Research Fund Association, the Council of Scientific and Industrial Research and the Indian Council of Agricultural Research.

Increased crop production by catalysts

Pot and plot culture studies conducted in this Department for a period extending over twelve years have shown that increased crop yields could be obtained on application to soil of certain inorganic chemicals, such as manganous sulphate and ferrous sulphate in small quantities. Laboratory studies have shown that this beneficial effect of the chemicals on crop growth is due to their hastening the decomposition of soil organic matter, thereby releasing larger quantities of plant food during the life-time of the crops. The action of these chemicals has been found to be comparable to that of hydrogen peroxide and potassium permanganate on soil humus. The chemicals get precipitated *in situ* as finely divided oxides and thereafter behave as catalysts to promote the oxidation of organic matter. Vegetation experiments have also shown that these inorganic catalysts have no deleterious effect on the succeeding crop.

Recently, it has been found that a product prepared from ferrous sulphate, by interacting it with burnt lime under easily controlled conditions, offers certain advantages over manganous sulphate or ferrous sulphate for use on a large scale, especially under unfavourable conditions. The catalyst product when applied to the soil at the rate of 40–80 lbs. per acre preferably after previous admixture with organic manure enhances crop yields to the extent of about 20%.

In view of the encouraging results obtained with this product, field trials have now been undertaken at different agricultural stations in South India with the kind co-operation of the Departments of Agriculture in Mysore and Madras and the Director of Research, Indian Coffee Board, with a view to studying its influence in the yields of various crops under different soil and climatic conditions.

Treatment of brackish water to render it palatable

In many areas of our country, the wells yield a water which has a material percentage of salts and minerals that not only render it unpalatable but also, in many cases, are the likely cause of little-investigated nutritional and health disorders of the people using it,

This study was undertaken to gather reliable data on the subject. Though methods of removing organic matter, turbidity or harmful germs are well known, there are no means of reducing the salt content of water besides the process of distillation.

As a result of recent researches materials which can absorb salts have been developed. The method requires merely the percolation of the brackish water through two types of synthetic materials known as the *Ion-Exchange Resins*—one bed material removes one half (the anionic) of the salt and the other bed removes the other half (the anionic) of the salt. The process requires little or no technical skill. When these materials are exhausted, they can be re-vivified by percolating dilute acid or dilute alkali and washing them free of the reagent.

A material suitable for this purpose from indigenous raw products has been developed. The actual process of water treatment and some models of filters for domestic and large-scale treatment have been prepared.

Endemic fluorosis

In certain parts of our country, there occurs a disease among men and cattle known as fluorosis. Its existence in India was first discovered in 1939 and it has been traced to the presence of small quantities of fluorides in the drinking water. When only a small quantity of this element is present in the water, the teeth of the children using that water get disfigured. But when the quantity is higher the bones are also affected. On the long bones, off-shoots like rose thorns appear and the condition is very painful. The flexible ligaments between the vertebræ become bone-like and the unfortunate victim is unable to bend his body or turn his neck easily. The cattle also lose condition and go lame.

A method which can be employed under rural conditions to remove this poisonous element from the water has been developed. The process is the same as in the case of salt removal, *i.e.*, the water is percolated through a special impregnated material. The filter material for this purpose is prepared by a simple process from paddy husk and is impregnated with aluminium salts before use.

A systematic theoretical study has been carried out on experimental animals on the physiology of calcium and fluorine. In this connection the phenomenon of mottling of teeth in rats, the influence of calcium and phosphorus of the diet on fluorosis in rats, the mechanism of fluorine removal by calcium salts *in vitro* and the effect of fluorine on the metabolism of calcium, phosphorus and nitrogen have been undertaken. Metabolic studies on fluorine in the system and its examination, retention, and distribution in soft tissues and skeletal parts, its toxicity, and antagonism of fluorine and iodine have been undertaken.

Antibiotics from medicinal plants

About 200 of the more important Indian medicinal plants have been surveyed for their antibiotic content. About 30–40 of these plants give aqueous or alcoholic extracts possessing highly antibacterial activity on *St. aureus* and *Esch. coli* (and a few special plants on special organisms). *Pterygospermin* from moringa roots and *Allicin* from garlic have been prepared in more or less pure forms. *Pterygospermin* combines a low toxicity to experimental animals and a good antibacterial spectrum.

Twelve soil actinomycetes from local garden soil were isolated and two of them found to be very good producers of antibiotic substances specially for the dysentery organisms.

Cultural studies reveal that complex sources of nitrogen favour antibiotic formation. Flooding increases streptomycin production and minerals like sodium and iron are essential for antibiotic formation.

Wheat bran extract and groundnut cake hydrolysates have been found to be eminently suitable for the growth and antibiotic production by *Act. griseus*.

The rôle of nucleoproteins on the mechanism of penicillin has been studied. The effect of magnesium ions on inhibitory effects of penicillin on insensitive pathogens have also been investigated. Magnesium ions render penicillin more effective in the case of gram-negative pathogens.

It has been found that the nature of the nucleic acid present in pathogens also determines the susceptibility or otherwise of the organisms to drugs like penicillin. Preliminary studies have

shown that the resistance of an organism is associated with the Ribo or Desoxy ribo nature of the nucleic acid and sensitization, or acquiring of resistance is connected with the shift of the equilibrium of Ribo nucleic acid or Desoxy ribo nucleic acid. It was also found by experiments with mixtures of penicillin and bacteriostatic dyes that synergic effects of a pronounced degree exist which explains the different mechanisms by which antibiotics act and bring about multiple simultaneous inhibitory effects in the growth and multiplication of the pathogens.

The effect of cooking and storage of foods in metallic vessels has been investigated. Researches on metallic contamination of foods have shown that tinned brass vessels are not very safe to use. Aluminium is less readily attacked and has no adverse effect on the growth of rats (experimental).

Intensive agricultural experiments were carried on in the field of nutrition, soil flora and the biological fixation of nitrogen with the use of molasses and other ingredients.

Bacteriology of the tuberculation in water pipes as a result of growth of iron bacteria has been studied.

Salt stain on hides and skins cured under Indian conditions were investigated and the causes and its remedy were found out.

The phenomenon of photosynthesis of proteins in plants was enquired into.

Investigation of vegetable milks

In view of the acute shortage of cow- and buffalo-milk in our country, the possibility of producing as supplements milk equivalents from vegetable materials was studied. Among the materials investigated, soyabean and groundnut have proved very suitable for this purpose.

Soyabean yields a milk very readily. Both the milk and the curd prepared from it can be used for edible purposes in the same way as cow- or buffalo-milk. The milk and the curd are easily digested and possess a high nutritive value. Experiments carried out on laboratory animals and feeding trials on hundreds of human subjects have yielded useful data on the nutritive value of the milk and curd. These results show that soyabean milk is about 85% as nutritive as cow's milk.

An attractive milk completely devoid of vegetable flavour can be prepared from groundnut which is plentiful in the country. Laboratory experiments on animals and on human subjects have yielded results to show that the milk is about 80% as nutritive as cow's milk. Milk prepared from a mixture of 75% groundnut and 25% soyabean has been found to have a higher nutritive value.

These vegetable milks from the groundnut and the soyabean can be prepared at a very low cost. They can be rendered available to the people at one-fourth to one-fifth the cost of cow- or buffalo-milk. In view of their high nutritive value and the low cost of production, they can act as effective supplements to alleviate the shortage of animal milk in India. Especially to the poorer sections of the people who cannot afford to purchase cow's milk, these vegetable milks offer themselves as economic foods of good nutritive value.

Processing of edible seed-cakes

Commercial samples of groundnuts, cottonseed, sesame and cocoanut seed cakes have been analysed for various constituents including vitamins. The biological values of the proteins and the gross vitamin 'B-complex' contents have been assayed by animal experiments. The supplementary values of the commercial seed-cakes to poor South Indian rice diet and a poor wheat diet, at the same level of supplement by weight at the same level of protein content have been determined. Groundnut, cocoanut and cottonseed proteins show a supplementary relationship with wheat protein but only the former two show a supplementary relationship with rice protein.

Optimal conditions for the pre-digestion of the four commercial seed-cakes by using papain hydrolysates have been prepared in a palatable and attractive form having the consistency of 'Marmite'. The proteins of all the seed-cakes except groundnut cake showed a drop in biological value on pre-digestion while the gross vitamin 'B-complex' content of the hydrolysate was greater than that of the corresponding seed-cake.

The biological value of the proteins of commercial 'Expeller' groundnut cake is nearly 40% greater than that of the sample of groundnuts from which it was prepared, while the vitamin values

remain practically unaffected. Experiments on the effect of steaming and autoclaving on the nutritive value of seed-cake proteins showed that there is a definite increase in the biological value of groundnut proteins on mild heat processing, while, in the case of the other seed-cake proteins, there is impairment in varying degrees in the nutritive value with heat processing. The close analogy of groundnuts to soyabeans in regard to the improvement in the nutritive value of the protein with different types of milk heat treatment and the impairment in the nutritive value on more drastic forms of heat-processing suggested the presence of a weak 'trypsin' inhibitor in groundnuts also. Preliminary experiments carried out on the *in vitro* digestibility by trypsin of a solution of casein in presence and in absence of an acid (pH 4·2) extract of groundnuts established the presence of such an inhibitor. The extent of destruction of the trypsin-inhibitor on different types of heat treatment for various lengths of time has been determined and the rôle played by the inhibitor in the low nutritive value of groundnut protein as present in groundnuts has been demonstrated by animal experiments.

The medicinal principle of Datura, aconite, *Pongamia glabra* and *Plumbago rosea* were investigated.

The anti-anæmic principle of liver was investigated and hydrolysates were prepared which could be utilised in the case of cirrhosis of liver. Large-scale application of this material in the case of children suffering from cirrhosis of liver has been undertaken in the hospitals and interesting results have been obtained.

The percentage of blood calcium in health and disease of human subjects has been investigated.

The vitamin B_1 content in cereals and pulses was investigated. The preparation of *ragi* malt, malt extract and its food value were found out and conditions for its manufacture standardized.

Pituitrin, Insulin and Pancreatin have been manufactured from glands secured from the local slaughter-house and their manufacture under Indian conditions standardized. A large quantity of such material were supplied to the Government of India to meet their medical requirements during the War.

Experiments were carried out to separate potash salts from molasses and conditions established for the large-scale recovery

of the same from molasses and the subsequent utilisation of the latter for industrial purposes.

An excellent plywood adhesive from groundnut cake was prepared for use under Indian conditions. A food powder free from fat and mal-odour but rich in protein and other ingredients was prepared from groundnut cake.

The vitamin C content of Indian gooseberry was found to be a very useful source for meeting the requirement of India and the preparation of the same under commercial enterprise.

An investigation was carried on to find out the vitamin content of the Indian dairy products and conditions were standardized whereby the destruction of the same under Indian conditions could be minimised.

An exhaustive series of experiments were carried out to determine the vitamin content of butter and ghee under Indian conditions. Researches were carried out to study the method of manufacture of ghee under Indian conditions finding out the defects of the same in the village process and standardization of conditions for its manufacture. It has been found out that with a little care and attention, it is possible to manufacture first-class ghee, rich in vitamins, under the extreme conditions of temperature and moisture occurring in India.

A series of experiments were carried out to determine the defects of the present methods of the detection of adulteration of ghee and a process was suggested, whereby the detection of adulteration of ghee could be undertaken with certainty and free from the defects in the old process.

Enzymatic and biological changes occurring in the storage of fruits, particularly mango, were studied and conditions were found out whereby slices of mangoes could be preserved in very good condition by cold storage and adjustment of its hydrogen-ion concentration with a very mild and safe preservative.

Investigations were carried on to standardize the conditions for the utilisation of limes and oranges in this country and preparation of bottled juices of the same for storage and export.

The biological process of digestion and absorption of edible oils have been thoroughly investigated. The effect of refining,

deodourisation and hydrogenation of the same have been investigated. Processes have been developed for the vitaminization of vegetable oils from locally available sources for improving the nutritive values. The phenomenon of rancidity occurring under Indian conditions in the edible oils have been studied in detail. Remedial measures for combating occurrence of rancidity under Indian conditions and the use of useful and safe antioxidants have been worked out. The vexed problem of controversy between edible oils and hydrogenated fat has been the subject of intensive study in this Department to find out the relative merit of hydrogenated fat and its utilisation under Indian conditions for human feeding.

Finally, the general tendency of the work has been to awaken an enduring interest in the biochemistry of life-processes; of late years, the vastly important subject of nutrition and food production has taken a first place in the activities of the Department.

ELECTRICAL TECHNOLOGY AND POWER ENGINEERING

In the year 1910 when development of several large electric power schemes were contemplated need was felt for a department for the training of electrical technology students who would meet the demand for the personnel, which would be created for these schemes. The facilities for the training of electrical engineers, which then existed in India, were meagre and it was decided to establish a department for the training of electrical engineers in the Indian Institute of Science.

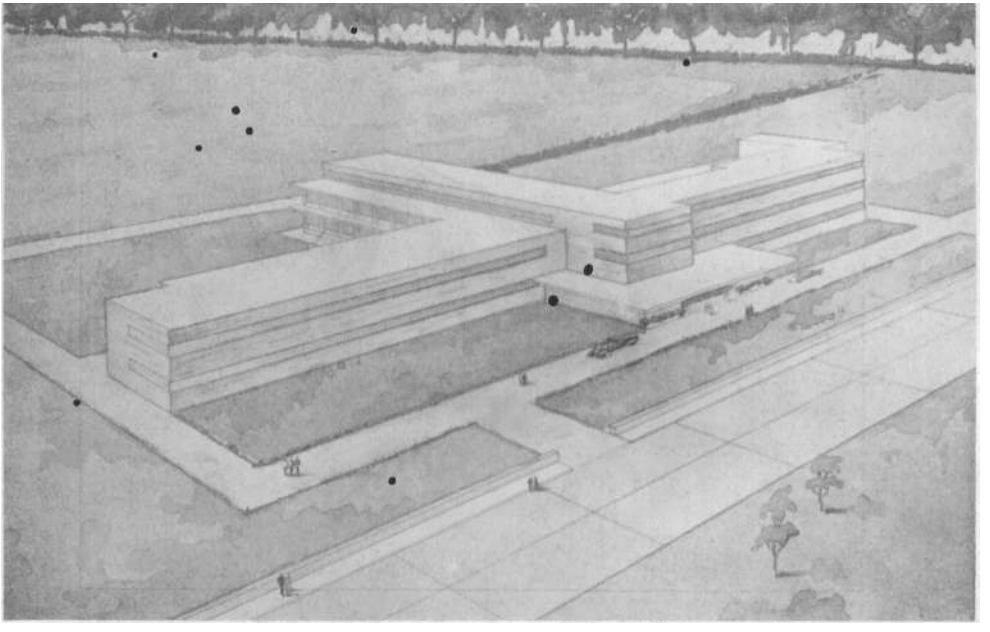
The Department of Electrical Technology at the Indian Institute of Science thus came into being, and the first session opened on the 24th July 1911. As the Indian Institute of Science was a post-graduate institution, admissions were restricted to graduates in science, and it was found that graduates were greatly superior to the others and in a much better position to take advantage of the opportunities of the study and research provided at the Institute.

The Department of Electrical Technology thus met the want of a training institute for electrical engineers and it is of interest to record that most of the present chief engineers controlling large electricity systems have been the students of this Department.

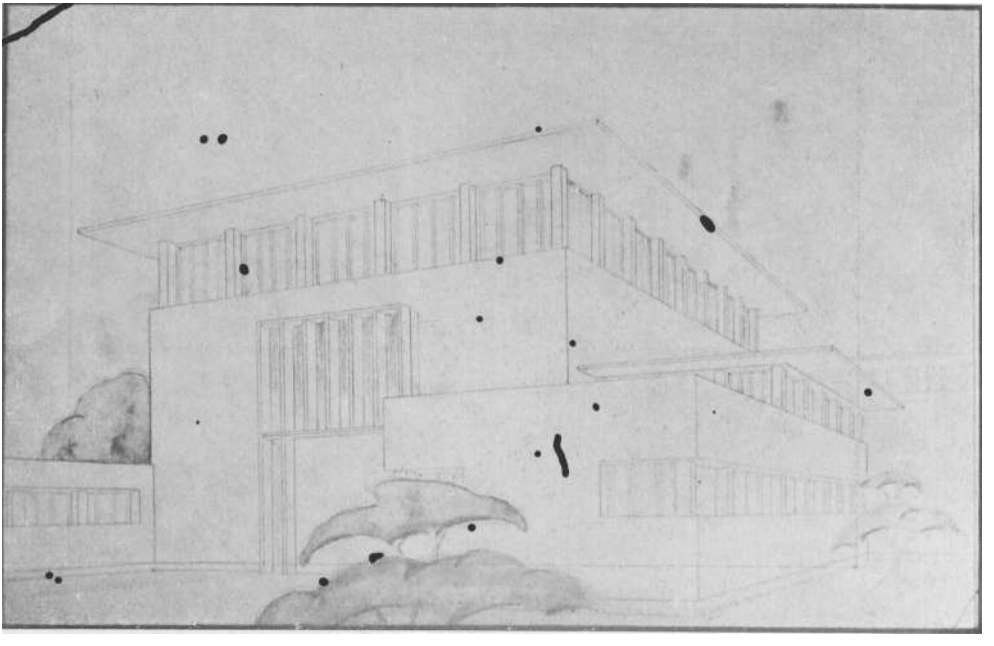
In the period of National Planning, during war years, when further large schemes of hydro-electric power developments were considered, the Indian Institute of Science again came to the fore and prepared a scheme for the training of the power engineers under the advice of an Expert Committee specially nominated for this purpose consisting of almost all the foremost engineers in the country. The Government of India blessed the scheme, gave its approval and financial support, and the new department is under formation at the Institute.

The new Power Engineering Department will admit engineering graduates, electrical, civil and mechanical, and will give them

PLATE VIII

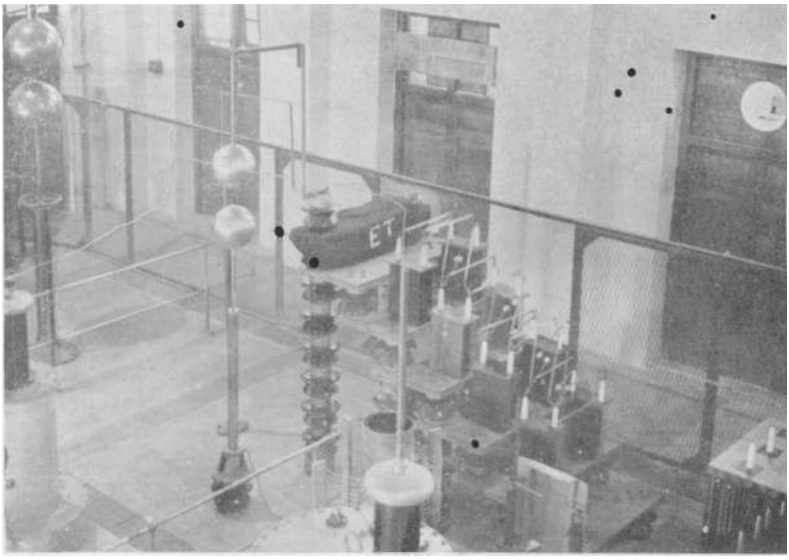


View of the building of Electrical Machines Laboratory

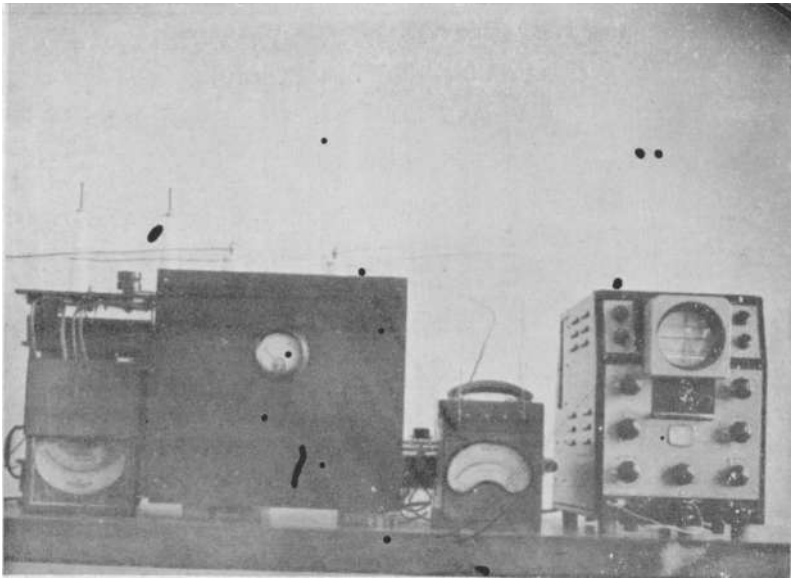


The High Voltage Engineering Laboratory

PLATE IX



Surge Generator (High Voltage Laboratory)



Constant Current Regulator

a specialized co-ordinated course allied and related to power development problems and train personnel of a higher order to meet the demands that would arise for the post-war power development schemes. This Department will thus meet a vital need and add distinction to the Institute.

It will have most modern and up-to-date laboratories and power plant. These will consist of modern electrical laboratories, hydraulics and hydro-dynamics laboratories, high voltage engineering and research laboratory, associated with an experimental extra voltage overhead transmission line, material testing laboratory, thermal power station and various workshops. The electrical laboratory will contain modern equipments of various types including latest developments and will not only provide means of carrying out routine practical experiments but also will provide means of investigating special problems in electrical machinery. In this laboratory there will be installed an A.C. Network Calculator which will afford means of solution of all-India power system problems by setting up systems in miniature and study the economics of interconnection and results of various switching operations. The electrical supply industry at present is handicapped regarding technical facilities in solving many of the problems and this calculator will contribute in no small measure towards a successful and rapid development of electric power. The hydraulics and hydro-dynamics laboratories will afford means of test in different problems of hydraulic machines, also on different problems such as design of high dams, protection works, etc. The high voltage engineering and research laboratory will be capable of producing a three million volt surge and a current surge of 100,000 amperes, and a million volt A.C. power testing. Problems in connection with the transmission line, and other problems such as arising from lightning disturbances, corona losses, will be investigated by the help of the equipment which is made available here, for the Central and Provincial Electricity Commissions. Another important contribution this laboratory could make would be a study of indigenous insulating materials that are now exported and re-imported in the country in finished form, and the electrical plant manufacturing industry in helping to solve problems of design in the manufacture of power plant.

The Power Engineering Department will also invite specialists and acknowledged experts in the various branches of engineering, with particular reference to power development, to give a course of lectures in their specialized fields which would prove valuable and serve professional engineers. There is very little engineering research being conducted in Indian universities and technical colleges in the electrical power and electrical plant design problems and this Department will provide facilities and encourage research which must to-day receive its due importance.

1. Sine Wave Generator Set

The Department of Electrical Technology designed and constructed a Sine Wave Generator Set consisting of three machines, embodying special technical features. The set was constructed primarily for the use of testing of electrical instruments sent to the Institute for standardization by various electrical supply authorities and industries.

The machine consists of a D.C. motor of a capacity of 10 h.p. driving two alternators each of a capacity of 10 kVA, the two alternators respectively being one for energizing the voltage and other current coils of the test instruments.

The special technical feature of the set consists of electrical means for obtaining the required phase displacement between the current and the voltage to enable the instruments to be tested at various power factors. This feature is novel when compared to the orthodox and conventional rocking-stator method. This is arrived at by the novel arrangement of the field winding which is wound for a three phase D.C. excitation and the whole system so arranged as to obtain the relative required positions and voltage and current by suitable rheostats.

Another technical feature is the use of the "Current "alternator on approximately short circuit instead of the usual load condition. This ensures the current wave form to be very near the sinusoidal.

This machine set strictly complies with the accepted B.S.S. standard tests in respect of wave form, and other requirements.

2. Design and Construction of a Low Voltage Heavy Current Generator

In the investigation of the electrochemical production of sodium and magnesium, which the Department of Electrical Technology was asked to undertake, necessity arose for a heavy current D.C. generator giving an output of approximately 1,500 amperes at low voltages.

An existing old rotary convertor machine in the Department was utilised to meet this requirement by incorporating a new design in the old machine and converting the same for this purpose.

The entire system of the winding, both for the armature and the field, was redesigned and a noteworthy feature was that no extra materials were requisitioned and all old materials retrieved from the stripping off of the machine were re-utilised.

This machine, after completion, was tested under all conditions and complied with all requirements including that of temperature rise, after a continuous running of a prolonged period. The machine was used for the purpose designed for originally, and subsequently for a long period with the pilot plant for the manufacture of sodium and magnesium.

3. Manufacture of Sodium

At the request of the Council of Scientific and Industrial Research, the Department of Electrical Technology undertook experiments during the war period for the manufacture of sodium and magnesium, in collaboration with the Chemistry Department.

The standard method of manufacture of sodium well known as the Castner Process, consists in electrolysing fused anhydrous caustic soda between electrodes of iron and nickel. As there were certain disadvantages in adopting this process owing to the scarcity of (1) the raw material, *viz.*, caustic soda and (2) the low current efficiency, resulting from the liberation of hydrogen in addition to sodium, investigations were made for the manufacture of sodium using sodium chloride as the raw material. A special cell was designed and developed which consisted of a mild steel sheet tank of square cross-section and open at the top. The lining of the cell consisted of asbestos, sillimanite and carborundum.

The anode was a graphite rod and the cathode of a refractory material and was provided between the anode and cathode, and bolted on to a chloride-collecting hood made of mild-steel sheet. Various experiments were carried out and the most suitable material for the diaphragm, correct composition of the electrolyte and suitable operating conditions electrically were determined and sizeable pieces of the metal were obtained.

Manufacture of Magnesium

The constructional features of the cells were more or less the same as for sodium, except that the cathode consists of a mild steel sheet tank of rectangular cross-section and the anode a rod of circular cross-section dipping from above. The cathode was lined on the outside with heat insulating materials. The diaphragm was made of porcelain. The operation of the cell was made by using external heating. The scheme proved successful, and resulted in producing sizeable product of magnesium.

4. High Voltage Laboratory

The Department of Electrical Technology was the first institution in India, in designing and installing an Impulse Generator to give voltage impulses of half a million volts.

Various condensers used in the making of the Surge Generator were constructed in this Department; also, the various High Voltage transformers.

A pioneer in giving instruction in H.V. Engineering and research, this Department is in the midst of a large expansion programme which will still keep its reputation as the most advanced and up-to-date institution in this field. A new and modern High Voltage Laboratory is under construction which will consist of an apparatus for the surge voltage of the order of 3 million, and power frequency voltage of the order of one million with a capacity of 1,000 kVA.

This new laboratory will be of considerable assistance to electrical and allied industries, and also for the high voltage transmission problems.

During the next few years there will be tremendous development both in electrical industry and electric power transmission,

The problem of transmission voltage, problem of insulation, will present problems to a research worker in the high voltage laboratory; porcelain and the varnish industries will also have to develop simultaneously to feed power plant and electrical machines industry.

Apart from large machines and transformer design, for the manufacture of porcelain insulators, hundreds of thousands of which will be required for transmission pylons in the country, no development can proceed without the help of a high voltage research laboratory for various tests which are the *prima facie* requirements of this particular manufacture.

There will be various problems in transmission line erection such as corona losses, surges, lightning and lightning troubles on which the high voltage laboratory will be able to carry out investigations and produce useful data to be incorporated in the design and the construction of the lines.

5. A.C. Network Analyzer

The present-day electric power systems have become so complex and complicated that any attempt at solution by mathematical and analytical methods is extremely lengthy and laborious, and, in some cases, impossible. The only satisfactory method in solving the various problems of the power systems, power transmission and distribution networks, and interconnection, is by a calculating board known as A.C. Network Analyzer.

At the Institute, a 480 cycle, A.C. Network Analyzer is shortly to be installed consisting of 16 generator units, 16 synchronous impedance units, 100 line units, 24 equivalent pi-line units, 50 load units, 32 auto-transformer units and 8 mutual reactor transformer units, and which will meet India's Electrical Power Industry's requirements for the next 20 years.

This equipment will be the first of its kind to be installed in India, and will provide a powerful tool for tackling various network problems, such as, short circuit studies for the determination of circuit breaker ratings, protection relay settings, ratings of current limiting reactors, and design of busbar supports, problems associated with system operation under normal conditions, such as, voltage regulation and current and load distribution, etc.

These problems are of vital importance to the economical layout of new power development and transmission systems. The Board is useful for system stability, and various design characteristics problems demanded by engineers from the view-point of economy of investment and operation of the system.

This Board will be used by the Central Electricity Commission, various Provincial and State Electricity Authorities, Central Waterpower, Navigation and Irrigation Commission, and other large private undertakings in the country, in all development and construction of the existing and projected power systems in India.

6. Manufacture of Carbon and Vitreous Enamel Resistors

At the request of the Council of Scientific and Industrial Research, Government of India, work was undertaken in the Department of Electrical Technology for the manufacture of carbon and vitreous enamel resistors.

Composition type of resistances incorporate carbon in the form of an electrical base, an inert material such as sand, talc, or asbestos as a filler and a binding material such as resin. The process of manufacture involves the preparation of the mix, moulding, heat treatment, coating the ends with a metallic film and fixing up of the terminals. After considerable experimentation, suitable moulding machines, heat treatment furnaces and the best operating conditions were successfully developed and the manufacture of the resistors on a semi-commercial scale standardized.

Wire-wound vitreous enamelled resistances are made by winding a special resistance wire (such as advance nichrome) of low temperature coefficient upon a refractory base. The base including the terminal connections is then coated with a produced glassy enamel and fired at red heat. The vitreous enamel embeds and protects the wire and is chemically inert with respect to the resistance element even at high temperatures. The vitreous enamel consists of an easily fusible silicate consisting of colourless glass rendered opaque by the addition of some colouring metallic oxide.

The choice of suitable ceramic tubes, wires and enamels are some of the important factors that affect the manufacture. The

requirements of the porcelain tube are that the body material of the tube should have good thermal shock resistance characteristics, in addition to mechanical strength and should be suitable for extrusion or moulding of round cores. The enamels used must be such that the thermal coefficients of expansion between the ceramic tube, the wire and the enamel are close together to minimize "crazing" of the enamel coating. Further the enamel must be melted on at as low a temperature as possible to prevent oxidation of the wire and subsequent change in resistance values.

Problems connected with the preparation of the enamel and its firing have been successfully solved and the process is now ready for commercial exploitation.

7. Design of Electricity Service Meters

Development work on the manufacture of A.C. house service meters was undertaken in the Department of Electrical Technology with a view to effecting improvement in the design of overseas meters.

The use of a permanent magnet as an eddy current brake is universal in meter practice and is quite common in other electrical instruments as a damping service. The distance of the axis of the pole faces from the axis of the rotating disc or vane is a very important consideration as the breaking torque per unit pole varies greatly with it. If this distance is denoted by D and the radius of the disc by R, the torque is small for low values of D. and rises more or less in proportion to it till it attains the value 0·82 R when it is maximum. For values of D greater than this, the torque falls rapidly and is zero when D is equal to R. As the maximum breaking torque occurs when D is equal to 0·82 R, the greater the portion of the pole faces at this distance, the more effective will the braking action of the magnet be.

This fact is not always appreciated in the design of the house service meter. Improvements in the design were effected based on this with the result that the cross-section of the magnet and hence its weight could be reduced. Alternatively, the cross-section of the magnet could be kept the same but the flux density reduced with the advantage that the permanency of the magnet could be increased, resulting in the meter keeping its calibration for a longer time.

Another improvement effected was in the reduction gear connecting the rotor shaft to the counter. In general the reduction is done in stages, by the use of a worm-gear or a spur-wheel. The frictional constant of the latter is very much less than that of the former. However, in most cases, there is a worm in one of the reduction stage, either in the first or in the second. In the new design the necessary reduction is completely brought about by means of spur-wheels, thus reducing the friction greatly.

A.C. single phase meters incorporating these modifications were evolved in the Department and a patent has been taken for the above-mentioned improvements.

8. Resonant Regulators for Constant Voltage to Constant Current Transformation

On certain electric circuits the operating conditions require a device which automatically maintains a constant current in its secondary circuit when supplied from a constant potential source. Constant current in such circuits is usually obtained by introducing series reactances, constant or variable, in the load circuit. Variable reactance regulators of the moving coil type are universally adopted for constant current circuits and their satisfactory service was partly responsible for other types of regulators not being developed.

In order to overcome certain inherent disadvantages of the moving coil type of regulators, a static resonant regulator is suggested. Resonant circuits for obtaining constant current were suggested as early as 1891 by Boucherot. Unreliability of condensers and their cost of manufacture at that time prevented further development of resonant regulators. Of late the subject has been revived and the work done in the Department of Power Engineering and Electrical Technology is a detailed study in the design, construction and performance characteristics of resonant regulators.

The design and construction of resonant regulators involved building up an efficient iron-cored reactor with a constant value of inductance. The design of such a reactor has been developed. Tests have been conducted on model reactors built according to that design procedure and found satisfactory.

For the study of the performance characteristics of resonant regulators tests are conducted and circle diagrams are drawn. The efficiency and other characteristics are compared with those of the existing types of constant current apparatus. It is found that the efficiency is (93%) very high, being similar to that of a transformer. Because there are no moving parts, adjustments to load changes are immediate and there are no overshooting effects during fluctuations. With new magnetic alloys being developed it is possible to further improve the efficiency and performance of this equipment.

The applications of this development are in many fields. Apart from the application in series lighting circuit the regulator can be successfully employed for production line testing, testing of protective equipment, relays and fuses. It can serve single phase loads such as electric furnaces from three phase power circuits. It forms a very useful component of the equipment for brightness control of approach lighting in Airports.

9. Design and Construction of ¼ H.P. Single Phase Induction Motor (Split-Phase Type)

An improvement on the older design has been completed in the Department of Electrical Technology, and an experimental motor is made.

A special concentric winding is used in this case to obtain a very silent running, the stator winding being designed in such a way as to give rise to a sinusoidal flux space distribution. In a simple single-phase concentric winding the main windings usually occupy two-thirds of the slots and the stator winding the remaining one-third and also all coils of the same winding have the same number of turns.

A radical departure from the above method is followed, and the results obtained with the modified winding in which the number of slots occupied by the main and auxiliary windings is the same, are satisfactory.

The motor on test has given satisfactory performance and efficiency. Further developments are in progress, which, it is anticipated, would result in a greatly improved type.

10. Single Phase Induction Motors

Improvements in the design and the performance of single phase induction motors incorporating new design which should broaden the field of application of single phase induction motors for industrial use has been presented.

Certain original changes have been suggested in the design of capacitor type motor which will greatly improve the performance. This improvement is an important departure from the older and usually adopted design for this type of motor. In recent years this type of motor has become one of the popular types in single phase motors, with the rapid application of motors to small machine tools, various domestic appliances, such as household refrigerator, air-conditioning plants, and small motors for cottage industries, such as looms, circular saws, centrifugal pumps, and so on. There is a great demand for fractional horse power motors of high quality.

The design which is evolved here gives a motor of very high performance, and also in the manufacture of it, for same conditions compared to the older design, reduces overall cost in the manufacture from 20 to 30%.

The papers containing these have been contributed to the American Institute of Electrical Engineers, where they have been approved for presentation, and to be published in their *Transactions*.

11. Testing of Iron and Steel Sheets Used in Electrical Machinery

The commercial methods employed for magnetic testing of iron and steel required large quantities of specimens. An apparatus for the testing of iron and steel sheets was developed and constructed in this Department and has the advantage over other known methods in finding magnetic properties in different directions quickly, and, at the same time, require comparatively small quantities of specimens.

The equipment consists of magnetizing coils fed from a sine wave alternator (also designed and constructed in the Department), the voltage being stepped down to a low value before it is fed to the coils, and the frequency of the supply controlled by

operating the rheostats in the field circuit of the D.C. motor driving the alternator. Within one limb of the solenoid are placed four coils, three of which are wound on the specimen and the fourth on a piece of glass, and the leads from these coils brought out for measurement purposes. The loss in the specimen is calculated by measuring the current, by making use of a thermo-couple and an A.C. bridge; other provisions are incorporated in the circuit to make accurate and speedy measurements. The flux density is determined by means of one of the coils on the specimen, and the flux wave-form by connecting the third coil on the specimen to a cathode-ray oscillograph. The whole procedure of testing is rendered simple and rapid.

A number of specimens which were supplied by the Tata Iron and Steel Co., Ltd., and other Indian industries were tested, with the method developed in this Department, very satisfactorily.

AERONAUTICAL ENGINEERING

This Department, which is of recent growth, provides advanced scientific and technical training for preparing engineers for leadership in aeronautics in India, in the various fields as they may develop in future: industry, civil aviation, the universities and technical colleges and the services.

There is a good laboratory equipped for advanced work in aerodynamics and aerostructures. The exhibits of this Department, though of high academic interest, will not fail to be of general interest also and are representative of some of the intricate equipment utilised for research in this field.

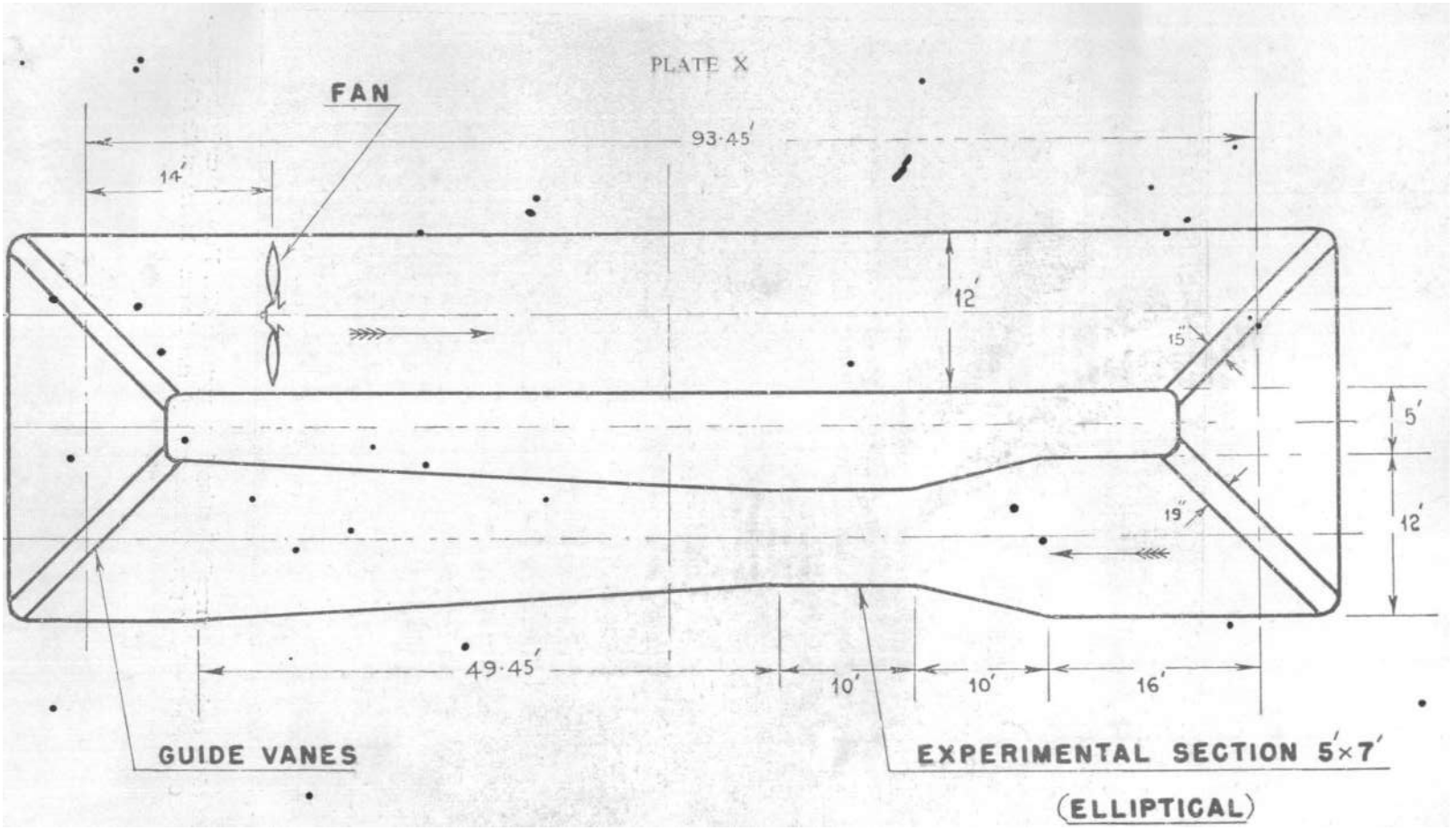
Given below is a list of the exhibits of this Department:—

1. Wind Tunnel.
2. Photo-Elastic Apparatus.
3. Strobotac.
4. Weybridge Smoke Tunnel.
5. Farren Smoke Tunnel.
6. Strain Gauge Apparatus.
7. Demonstration Water Tunnel.
8. Model of the Wind Tunnel.
9. Test model of a plane under design.

1. The Wind Tunnel

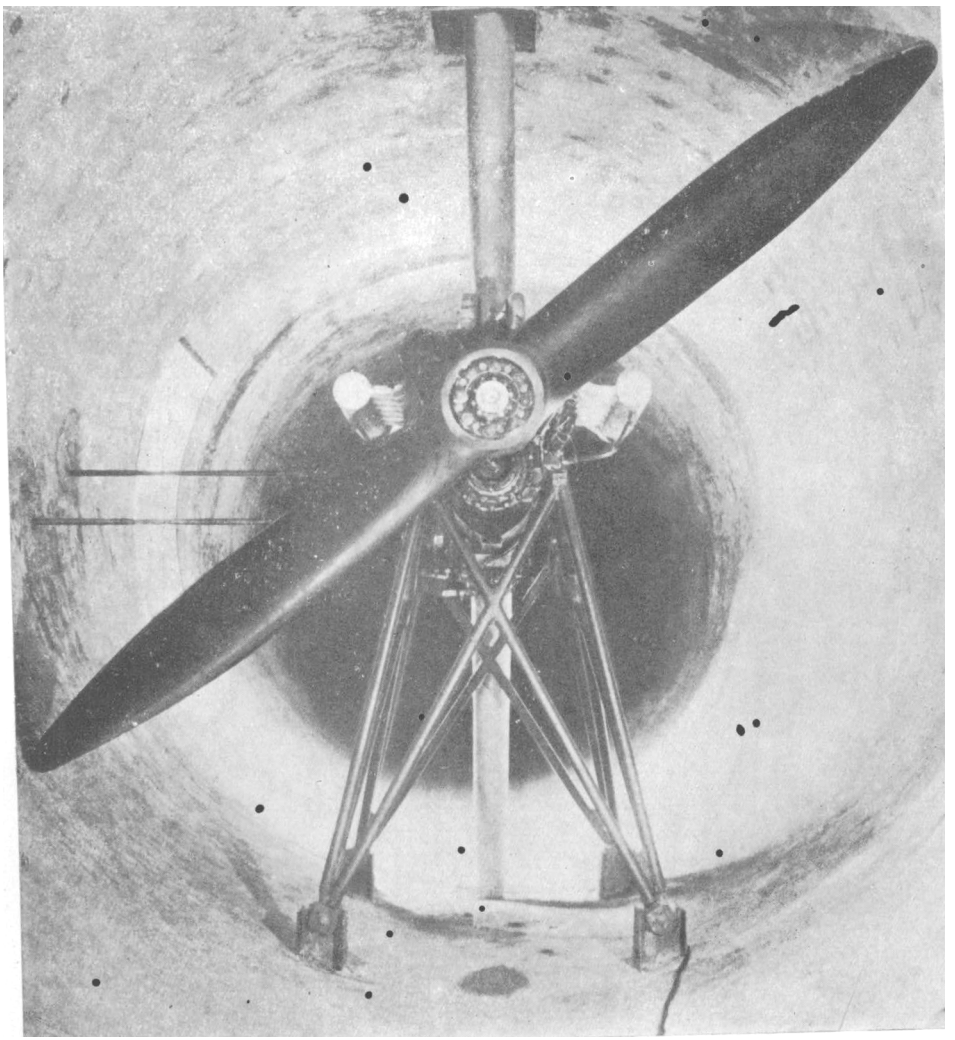
One of the most important implements in the hands of an aeronautical engineer is the Wind Tunnel. He looks forward to it whenever he gets any technical difficulties which cannot be solved by mathematical means or has to develop new types of aeroplanes.

PLATE X



Wind-tunnel Plan

PLATE XI



View of the engine and propeller looking from upstream side. Note the engine mounting. Cooling and exhaust pipes (bottom and top) and the control tubes at the side.

The wind tunnel of the Indian Institute of Science is constructed entirely of concrete, except the working section, which is made of steel. The overall length of the tunnel is approximately 221 feet. Except at the working section and the convergent and divergent cones, the tunnel is circular in shape, the diameter being 12 feet.

The wind stream is maintained by a two-bladed fan and made to circulate round the tunnel at a steady rate. At each corner there are vertical guide vanes, shaped like aerofoils, which help the air stream to turn the corners with as little disturbance as possible.

The forces on the model are measured on the balance: the lift (vertical), the drag (horizontal) and the side force. These forces multiplied by the appropriate factors give the forces that will be experienced by the full-scale aeroplane, subject to certain corrections. In this way the wind tunnel is an essential means of help in the design of new aeroplanes. Modern aeroplanes are the outcome of many years of research in wind tunnels.

In order to reduce disturbance in the flow, the size of the tunnel section is kept large (12 feet in diameter) until the working section is approached. Here, it is narrowed down rapidly to increase the wind speed. Beyond the working section the tunnel expands very gradually, reducing the wind speed and increasing the pressure, reaching 12 feet in diameter just before the next corner. The expansion has to be gradual in order to maintain a smooth flow of air.

The working section is elliptic in form, measuring 7 feet across and 5 feet in height. This is the narrowest part of the tunnel; we get speeds of air up to 210 m.p.h. at this section.

A model aeroplane is erected at the working section of the tunnel and is fixed (by means of solid supports) to a balance below the tunnel.

In the present installation, the fan is driven by a Rolls Royce Kestrel engine which develops 480 h.p. at 2700 r.p.m. This method of drive was a wartime make-shift device. To facilitate

a finer speed control this engine will be replaced by an electric motor. The diameter of the fan is slightly less than 12 feet, so as to fit the tunnel with a small clearance.

A 1/20th-scale model of this wind tunnel is also exhibited to give a clear idea of the general layout.

2. Apparatus for the Photo-Elastic Method of Stress Measurements

This method of stress measurement utilises the changes in the optical properties of transparent isotropic materials, such as celluloid or bakelite, when subjected to various types of stresses.

It is well known that under the action of stresses these materials become doubly refracting; and if a beam of polarized light is passed through a transparent model under stress, a picture with dark and light fringes is obtained. The stress analyst utilises this picture with other additional data to calculate the stress at any point of the model.

A mercury vapour lamp is used as the source of light. A monochromatic light of green colour is obtained by cutting out the other colours from the mercury light by means of colour filters.

Polarizer.—The light is now passed through an optical medium which allows the passage of light waves vibrating in one plane only—technically called, "Polarized light".

This polarized light is now passed through the model mounted to suit the loading requirements. On account of the changes in the optical properties of the model, caused by the stresses, the polarized light will travel at different velocities in any two perpendicular directions and consequently there will be a phase difference in the emergent light in these two directions. It can be shown that the difference in the principal stresses is proportional to this phase difference.

The measurement of the phase difference is effected by using the phenomenon of interference. For this purpose we use another polarizer—now called Analyser. It is placed in such a way that its axis and that of the polarizer are at right angles,

The picture cast on the ground glass under these circumstances has got some special features. It can be shown that the intensity of the light is a function of the phase difference and hence a function of the difference of the principal stresses. Evaluating the actual stresses is only a problem in simple mathematics from this stage.

3. The Strobotac

This instrument is used for the measurement of speeds of rotating machinery, from 600 to 14,000 r.p.m. directly, and to 50,000 r.p.m. by indirect methods. It can also be used for stroboscopic observation of moving objects.

The strobotac consists of a power supply, an oscillator for controlling the rate at which the lamp is flashed and a flashing lamp called the strobotron. By turning a knob the frequency of the oscillator and hence the flashing speed of the lamp can be adjusted to any value within certain limits.

After the necessary checking operations are done, the instrument is held so that the light from the strobotron lamp falls on the part to be observed and the knob which controls the flashing rate is adjusted so that the moving part appears to be standstill. An illuminated dial-scale gives the speed directly in r.p.m.

4. The Weybridge Smoke Tunnel

Description.—The tunnel is of the straight through or N.P.L. type. The air enters the working section through a contracted passage at whose entrance is a fine wire-gauze. This gauze gives the air the necessary stability which is required for smoke filament work. The working section is 18" square and of sufficient length to give a complete picture of the smoke filaments over the model and, what is as important, behind the model. The front of the working section consists of a removable glass panel through which the smoke filaments can be observed. These filaments are rendered especially visible by a lighting system arranged above and below the working section. The smoke is made of vaporized paraffin. The smoke passes from the apparatus below the tunnel

into the air-stream. The filaments of smoke so produced are evenly spaced and take up the direction of the air-stream. If a model is now introduced into the working section, the disturbance of the air from its original path will be indicated by the disturbance of the smoke filaments.

This smoke tunnel is also provided with a balance to measure the lift and drag forces. The tunnel can therefore be used for quantitative measurements also.

All the controls are located conveniently on one control panel in front of the tunnel, near the working section.

5. Farren Smoke Tunnel

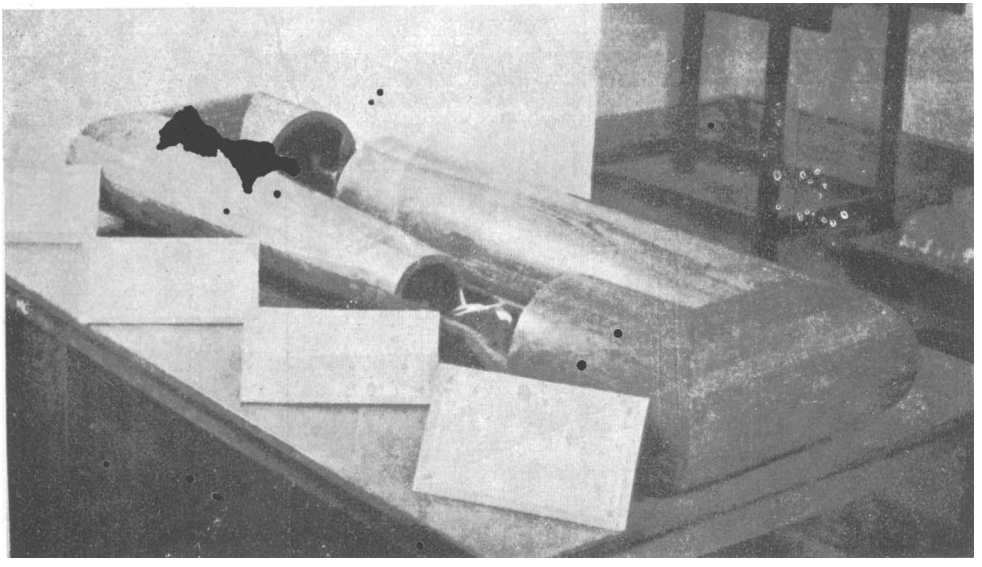
The purpose of this tunnel is essentially the same as that of the Weybridge tunnel though it is not capable of giving any quantitative results.

Here, the experimental section is a fairly small one and to make observations easy, the flow pattern is projected on a screen by means of a system of lenses and a powerful source of light.

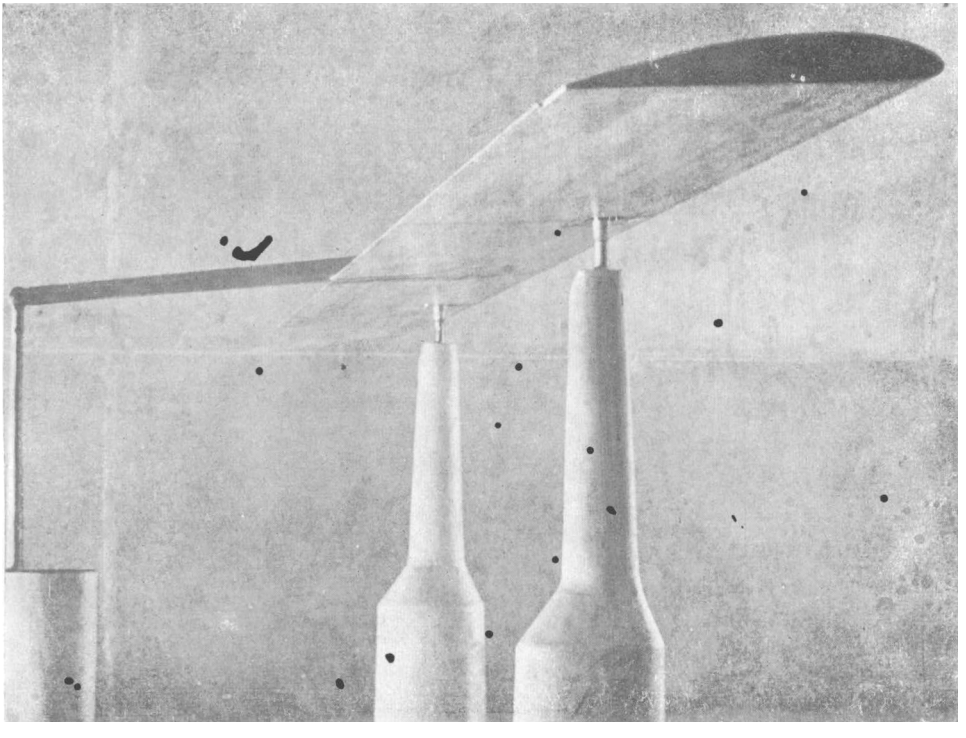
6. The Strain Gauge Method of Stress Instruments

The strain gauge apparatus is an electronic instrument used specially to measure dynamic strains or record static strains from a distance, when it is not convenient to measure them from near due to limited space or proximity to danger. The apparatus measures any physical strain by electric means, by converting a physical magnitude into an electrical magnitude.

This apparatus is a variable resistance strain gauge and consists of an element of a special alloy, which is glued to a structure at the point where the strain is to be measured. The strain of the body is wholly transmitted to the gauge which suffers a change in specific resistance owing to the physical strain. This change in specific resistance upsets the balance of a simple electrical bridge, of which the gauge wire is an arm. From a knowledge of the Gauge Sensitivity Factor, which is the ratio of the proportional change of resistance to the physical strain of the gauge, the physical strain suffered by the gauge can easily be computed. In this instrument, the strain can be read directly in micro-inches per inch.

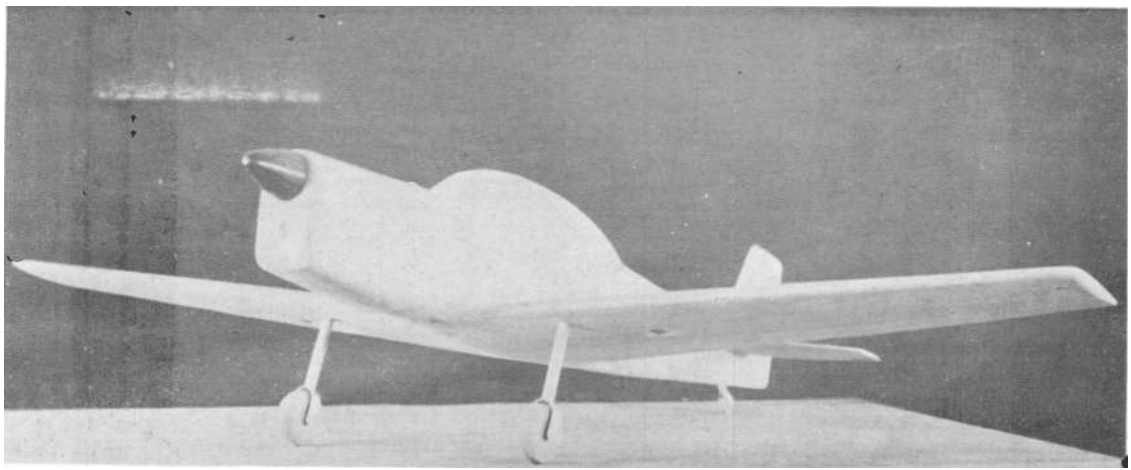


1/20 th-Scale model of wind tunnel



A close view of an aerofoil mounted on the wind tunnel for test. Note the details of connection between the model and the balance struts.

PLATE XIII



Test model of a plane

7. Demonstration Water Tunnel

This Tunnel designed in our Department, makes use of fine particles suspended in a liquid medium to get the flow pattern. Turbulence is caused at very low speeds in the liquid; so the tunnel will be of help to examine flow patterns at low speeds only. Movement is imparted to the water by means of a propeller, located in one of the vertical legs and driven by a motor.

8. Model of the Wind Tunnel

This is a 1/20th-scale model of the main wind tunnel of the Department.

9. Test Model of a Plane under Design

This is a 1/6th-scale model of an aeroplane that is being designed in India. The model is intended for conducting tests in the wind tunnel for getting performance and stability data.

PHYSICS

Introduction

The Department of Physics at this Institute was started by Sir C. V. Raman in April 1933 and research students were admitted in July of the same year. Under his energetic leadership a school of fundamental research in physics was established which to-day has to its credit a remarkable record of original work and has earned for itself a high scientific reputation all over the world.

The work of the Department may roughly be classified under two heads:

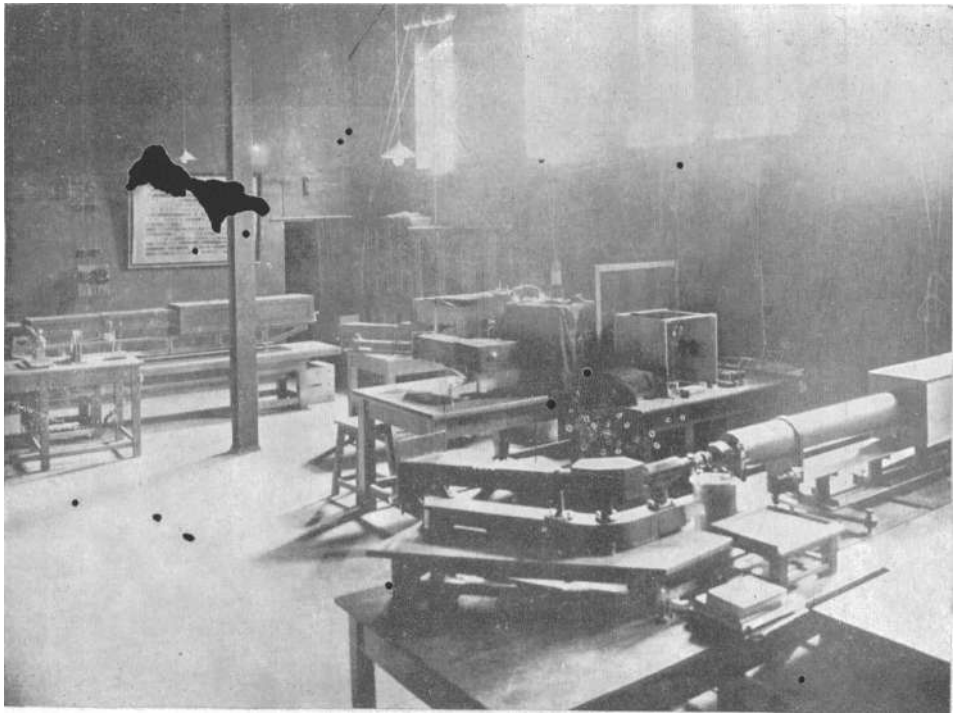
(i) Theoretical physics, and
(ii) Experimental physics,

greater emphasis being placed on the latter. Valuable contributions have been made in the following subjects:

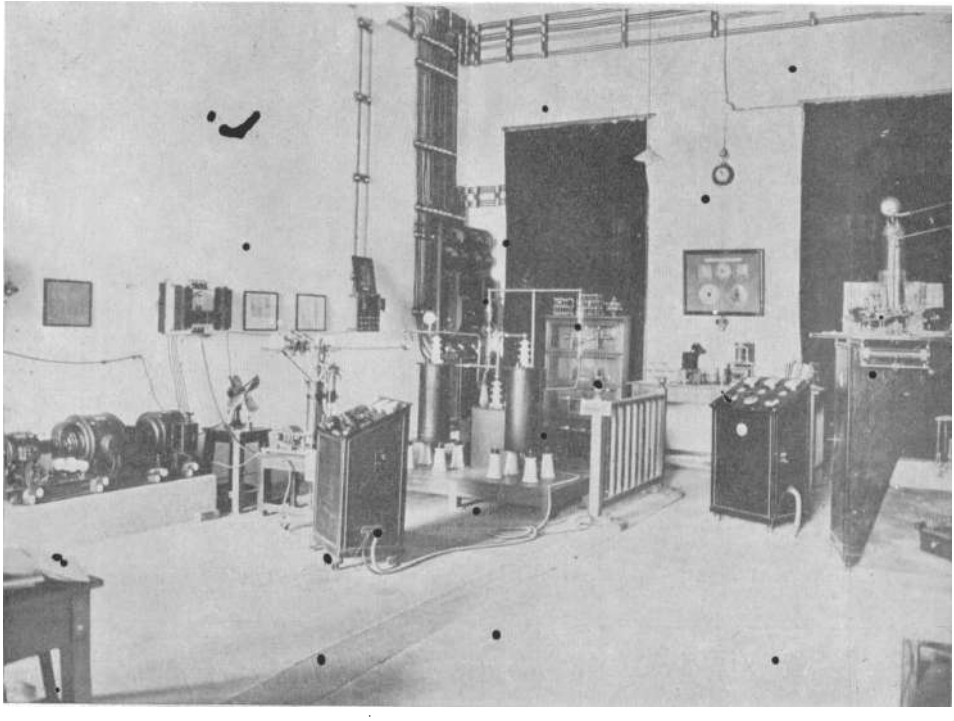
(i) Molecular scattering of light,
(ii) Colloid studies,
(iii) Ultrasonics and hypersonics,
(iv) Raman spectra,
(v) Crystal physics,
(vi) Dynamic reflection of X-rays,
(vii) Physics of the diamond,
(viii) Optics,
(ix) Line and band spectra,
(x) Magnetism and magneto-optics,
(xi) Dielectric behaviour,
(xii) X-rays and electron diffraction,
(xiii) Mathematical physics, and
(xiv) Miscellaneous.

Since the inception of the Department in 1934, more than 500 publications have appeared in the regular scientific periodicals covering well over 4,000 pages.

Reviewing the history of the activities of the Department two features stand out prominently. The first is the extent to

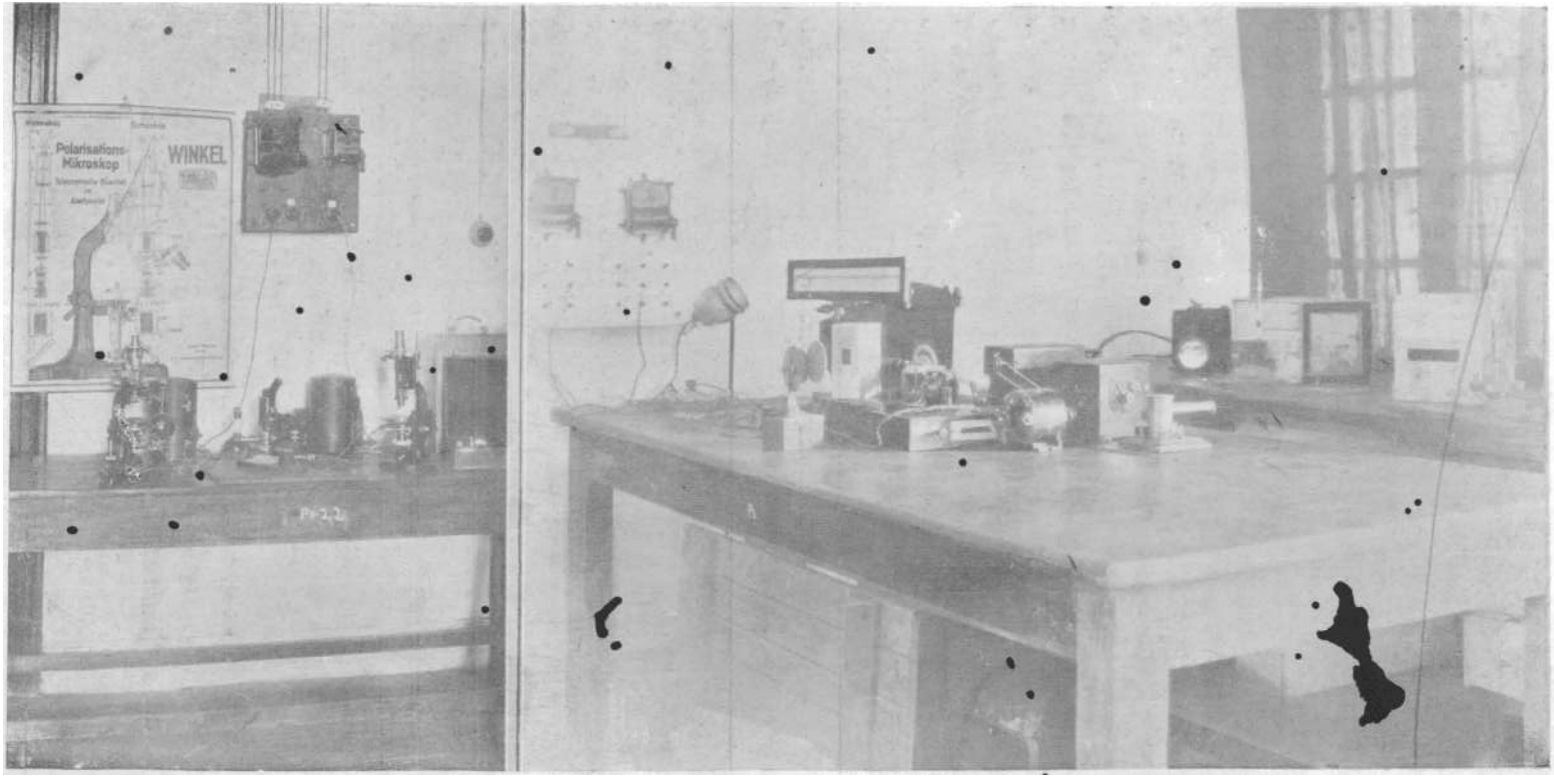


Spectroscopic Laboratory



X-Ray Laboratory

PLATE XV



Crystallographic and Infra-red Laboratories

which independent research has been encouraged in the Department. The great majority of the papers so far published represent the work accomplished and written up by the students themselves with the minimum of supervision and assistance. This policy has been very successful in discovering some exceptionally gifted men and in building up self-reliance in others not so highly gifted. The second feature is that there has been a very large and very significant output of new knowledge which has attracted the favourable notice of the scientific world as is evident from the large number of references to the work done by the Department in treatises and books published abroad. In this review we shall refer to the more important contributions from the Laboratory.

1. Light-Scattering and Colloid Optics

One has only to recall the pioneer investigations of Faraday, Tyndall and Zsigmondy to realise the importance in colloid science of the study of the optical properties of colloids. The most important optical property and one of the subjects which has been extensively studied from the early days of colloid science is the Tyndall phenomenon or the scattering of light during its passage through the colloidal medium. For the first time in the study of this phenomenon, the importance of the use of plane polarized light was pointed out by Dr. R. S. Krishnan who carried out a detailed study of the Tyndall effect in colloids in its theoretical and experimental aspects with a view to finding its general laws without restrictions regarding the size, shape and structure of the colloidal particles. An important step forward in this field was made by the discovery of a new optical effect—referred to as the "Krishnan Effect"—relating to the state of polarization of the Tyndall light. The effect can be easily demonstrated (Exhibit No. 1) as follows:—A beam of common light is first divided by a double-image prism into two beams of equal brightness, one polarized with vibrations vertically and the other polarized with vibrations horizontally. The two beams are then allowed to pass through any colloidal medium. The two Tyndall beams are viewed transversely through a second double-image prism as a result of which each of them appears double. Four Tyndall tracks would then be seen side by side. The new effect in the

first place is the discovery of the reciprocity theorem, namely, the second and the third of these tracks are invariably of the same colour and intensity. The extreme generality of this relation is remarkable. It is equally true for the commonest of turbid media, such as muddy water, or a solution of soap and for very pure diffusing media such as dust-free gases and liquids. In all the cases where the diffusing particles are spherically symmetrical, the second and third beams are comparatively absent, this being the case irrespective of whether the particles are large or small. On the other hand, the fourth of the Tyndall tracks is not generally equal in intensity either to the first or to the second and the third. Its brightness relative to the first depends greatly on the size of the particles and may, in fact, be regarded as a measure of the same. These observations lead to the conclusion that in order to get a correct idea of the state of dispersion of the scattering elements in any colloidal medium, it is necessary to make a comparative study of the state of polarization of the Tyndall light with the incident light in different states of polarization.

Basing himself on this relation, Dr. Krishnan developed delicate optical methods to determine the polarization characters of the scattered light, which culminated in the discovery of the anomalous polarization of the light transversely scattered by certain substances when the incident light is polarized with its electric vector in the direction of observation. This has been attributed to the existence of particles or molecular aggregates whose size is not small compared with the wave-length of light. It is observed not only with colloids, but also in liquid mixtures nearabout the critical solution temperature and by optical glasses showing that they contain large aggregations of molecules. Since, by making quantitative measurements of the effect on colloids, inferences can be drawn regarding the structure, size and shape of colloidal particles, the method developed by Krishnan has found important applications in many branches of science which deal with particles of colloidal dimensions, like high polymer science, rubber technology, etc.

2. Ultrasonics and Hypersonics

Mechanical oscillations of any material body (*e.g.*, a bell) produce the physiological sensation of "sound" on the human

ear if the "frequency" or the number of cycles per second lies in general between 30 and 16,000, and in exceptional cases of people even up to 30,000 c.p.s. For this reason, the range from 30 to 30,000 is termed "sonic". If the frequency exceeds 30,000 c.p.s., however, the "sound" becomes inaudible since the ear becomes insensitive to such rapid vibrations. Sound with frequencies over 30,000 cycles is therefore, called "Ultrasonics" or "Supersonics". These high frequency vibrations are produced in general by the use of the so-called piezo-electric crystals like quartz, tourmaline, Rochelle salts, cane sugar, etc. These have the peculiar property that if we apply an electric potential along certain directions in them, they expand or contract, depending on their nature. Taking advantage of this, high frequency radio voltages, easily obtainable by the use of suitable thermionic valves, are applied to thin plates of these crystals cut in various ways. They vibrate therefore with the applied frequency, producing ultrasonic oscillations.

Since the time of the first Great War, the subject of ultrasonics has acquired a phenomenal importance in a variety of ways. They have been successfully used in communication, submarine detection, etc., in war time. In peace time, they are extensively used in television, testing materials for detecting flaws and in some chemical industries like preparation of difficult alloys, colloids, aging of wines, etc.

When such ultrasonic vibrations are impressed on a liquid under suitable conditions (Exhibit No. 2), there exist in the material alternating regions of compressions and rarifactions. If a beam of light traverses such a medium the peculiar phenomenon known as "diffraction" or "splitting up" of the beam into number of bands occurs. This was first discovered by Debye and Sears. The present experiment is intended to show this effect.

Though this phenomenon was discovered as early as 1932, a satisfactory theoretical explanation of the same was not forthcoming until 1935. A significant contribution to the field of ultrasonics has been made by Sir C. V. Raman and Dr. N. S. Nagendra Nath by their theory of the diffraction of light by ultrasonic waves. The theory is based on the simple idea that the light in passing through the field of ultrasonic waves suffers

changes of phase in proportion to the amplitudes of the sound waves. The theory is found to give quantitative explanations of practically all the phenomena observed both in this laboratory and elsewhere. A complete generalization of the theory has also been given which explains certain phenomena not explained by the elementary theory, such as the "reflection" of light by the ultrasonic waves. Various results to be anticipated on this theory, such as the effect of oblique incidence, diffraction by superimposed waves and the periodic visibility of the diffraction effects have been worked out and verified by other workers in the laboratory.

A large amount of work has also been done on the determination of ultrasonic velocities in more than a hundred organic liquids and also the dispersion of the velocities in the acoustic spectrum.

In the Raman-Nath theory, it had been shown that the diffracted light must have a frequency different from the incident light, the frequency difference being that of the sound wave. This effect, although undetectable with ultrasonic waves, has been demonstrated with "hypersonic" waves, *i.e.*, the spontaneous high frequency acoustic waves of thermal origin present in liquids. These waves reflect the light waves, resulting in a change in frequency as in the Doppler effect. The alteration in the frequency has been demonstrated by studies made with a Fabry-Perot etalon, when two frequencies symmetrically displaced on either side of the incident frequency are observed. An interesting feature that is observed in these studies is the presence of an unmodified central line, which has been ascribed to the presence of molecular clusters.

Studies made on the frequency shifts in these experiments have made it possible to calculate the velocities of the hypersonic waves and thus to extend the dispersion data of acoustic velocity to this region. An interesting fact, discovered by Dr. C. S. Venkateswaran, is that the hypersonic velocity in the case of highly viscous liquids, such as glycerine is appreciably higher than the sonic and ultrasonic velocities. This shows that such liquids exhibit appreciable rigidity at these high frequencies and pass over into the solid state.

The existence of sound waves of thermal origin in a solid has been demonstrated by Dr. R. S. Krishnan in a simple way. He has photographed the Doppler shifts of frequency due to the scattering of light by thermal waves in diamond and corundum. The success is mainly due to the fact that the velocity of sound in these crystals is large. The resulting Doppler displacements in the frequency of the 2536·5 radiation scattered transversely are large enough to be recorded directly without interferometric aid using a quartz spectrograph of moderate power.

3. The Raman Effect

One of the most important lines of research actively pursued in the Department of Physics ever since its inception concerns itself with the "Raman Effect" or the spectroscopic study of the light scattered by transparent substances. If we irradiate any substance, a solid, liquid, or gas, with a powerful beam of monochromatic light and analyse with a spectrograph the light scattered by it, the spectrum of the scattered radiation shows over and above the lines present in the spectrum of the incident radiation, new lines, or bands (Raman scattering) shifted from the parent line to different extents. Each line in the incident spectrum, provided it is of sufficient intensity, gives rise to its own Raman scattering and the frequency shifts, relative intensities and other features of the new lines and bands are independent of the exciting radiation and are therefore characteristic of the substance under investigation. Twenty years have now elapsed since Sir C. V. Raman discovered this phenomenon, but the method still continues to be an invaluable tool to the physicist and chemist alike in solving problems relating to the structure and constitution of matter.

The experimental arrangement commonly employed for recording Raman spectra is quite simple and Exhibit No. 3 shows one such arrangement. Essentially, the method is to focus on the substance to be investigated (which is housed in a suitable container), monochromatic radiation from a source, generally a glass or quartz mercury arc. The scattered light is led out in transverse direction and focussed on to the slit of a spectrograph and recorded on a photographic plate.

The Raman effect has been employed with great success in

these laboratories to throw considerable light on numerous physico-chemical problems connected with the different states of matter. Special mention may, however, be made of the important applications concerning the interpretation and elucidation of molecular spectra, electrolytic dissociation, association, polymerization, change of state, molecular rotation, crystal structure and a host of other allied problems which have been investigated with conspicuous thoroughness. A number of improvements and modifications of the general experimental procedure have been made from time to time to facilitate these studies. To mention only one, a significant advance in this direction was the development of the new technique of complimentary filters for photographing the Raman spectra of crystal powders. This has opened out for investigation the vast array of crystalline compounds in the domain of organic as well as inorganic chemistry, which remained till then meagrely studied.

The importance of using highly monochromatic and intense sources of excitation cannot be overstressed, especially for investigating substances in which scattering is very feable, *e.g.*, crystals. It is also very essential that there should be no unwanted radiations and no continuous spectrum accompanying the exciting line. Further, it is highly desirable that the exciting radiation should be removed from the scattered light before its entry into the spectrograph as, otherwise, the photographic plate would be fogged by its general diffusion within the instrument. The λ 4047 and λ 4358 radiations of the mercury arc which are most commonly employed for exciting Raman spectra do not satisfy these requirements. But the λ 2537 radiation which was used by Rasetti for the first time in 1930, in addition to its possessing these advantages, enables the use of quartz spectrographs with their enhanced dispersion in the ultra-violet region.

Foreseeing this, Dr. R. S. Krishnan developed the technique of using the resonance radiation with the maximum advantage and has applied it with singular success to the study of the Raman spectra of crystals. In essence, it consists of using a water-cooled low pressure quartz mercury arc, in which the self-reversal of the λ 2537 radiations is effectively checked by squeezing the discharge against the front wall of the arc by an electromagnet, and by

selectively filtering off the exciting radiation from the scattered light by absorption in a screen of mercury vapour, thus facilitating the observation of low frequency Raman lines. This technique has been employed by him to study the Raman spectra of a large number of crystals including diamond, rock-salt, sylvine, potassium bromide, ammonium halides, calcite, quartz, barytes, gypsum, etc., and has yielded a rich harvest of results. These results fully confirm the new theory of lattice dynamics put forward by Sir C. V. Raman, which is referred to in the next section.

4. Crystal Physics

Sir C. V. Raman's new theory of the atomic vibrations in crystals has opened up a wide field of research, and the activities of the Department in recent years have mainly been devoted to studies in crystal physics. According to Raman's theory, the vibration spectrum of a crystal lattice consists of a finite number of discrete frequencies, the modes of vibrations corresponding to these frequencies being such that equivalent atoms in neighbouring cells in the lattice vibrate either in the same or in opposite phases. From extremely simple considerations, we reach the general result that the structure of a crystal containing atoms in each cell has $(24p-3)$ normal modes of vibration, while in the remaining $21p$ modes, they have the same amplitude but alternately opposite phases in successive cells along one, two or all three axes of the space lattice. The three omitted solutions represent the three simple translations. The number of distinct normal frequencies would necessarily be less than $(24p-3)$ if the crystal possess additional elements of symmetry. The results of the theory have been worked out for a number of crystals having simple structures and the number of characteristic frequencies have been calculated. These have been verified by studies on their Raman spectra made by Dr. R. S. Krishnan using the specially developed technique of employing the 2537 Å. radiations of the quartz mercury lamp. The results obtained by him in the case of diamond, rock-salt and ammonium halides afford a direct experimental verification of the predictions of the new theory of crystal dynamics, *viz.*, that the vibration spectra of crystals consist of a finite number of discrete frequencies. His

results on diamond deserve special mention, since the lines in this case have been shown to remain sharp even under very high dispersion, thus proving that the vibration frequencies are highly monochromatic.

5. Dynamic X-Ray Reflections in Crystals

The first great landmark in the history of the diffraction of X-rays by crystals is the brilliant linking up by Laue of the diffraction patterns with the internal architecture of the crystal. Following up this remarkable discovery, Bragg showed that a crystal would behave as if it were a collection of reflecting planes of atoms which would diffract an incident X-ray beam according to a mathematical law which has now become famous as the Bragg equation. The calculation of the intensities of these reflected beams soon followed, with the result that X-ray analysis has now become the most powerful tool in the elucidation of the structure of solids.

The apparatus employed in these investigations is very simple (Exhibit No. 5). A beam of X-ray is limited by slits into a narrow parallel pencil which falls on the crystal mounted on a rotatable stage ('goniometer'). The diffracted beam is caught in a detecting chamber, the detection being effected by the chemical effects of X-rays on a photographic film or their electrical effects on certain gases.

As is well known, the infra-red vibrations in a crystal can interact with visible or ultra-violet light, resulting in a change of frequency of the latter in the scattered light. A similar interaction of the lattice vibrations with X-rays was foreseen by Sir C. V. Raman and actually shown to occur by him and Dr. P. Nilakantan. The actual mechanism is, however, different with X-rays. The change in frequency of the X-rays is too small to be determined, but the interaction of X-rays with the crystal lattice results in a tilting of the reflecting planes of the crystal, and thus giving rise to new 'dynamic reflections' in directions away from the Laue reflections. Such dynamic reflections have been observed with a large variety of crystals. The investigations with diamond support the theory particularly well. It has been suggested by other workers in the field that the extra reflections are not due to the infra-red vibrations, but to the presence of

elastic waves of low frequency. That this is not so has been proved by the sharpness and specular nature of the reflections and also by the fact that the positions of the dynamic reflections can be quantitatively accounted for by the theory.

6. The Physics of the Diamond

From the very beginning, investigations have been made on the structure and properties of diamond. In 1934, Dr. Nagendra Nath made studies on the lattice structure of diamond and gave the correct interpretation of the vibration of frequency 1332 cm.$^{-1}$ As a result of the acquisition of a collection of diamonds made by Sir C. V. Raman, an impetus was given to researches in this branch since 1941. A large variety of properties of diamonds have been investigated and many new results have been obtained. The most interesting result that has emerged from these studies is the fact that diamonds show large variations in its properties from specimen, to specimen which must be attributed to inherent variations in its structure and not to the presence of any extraneous impurities. The interpretation of this fact remained obscure until Sir C. V. Raman put forward his theory of the structure of diamond. The internal structure of diamond is based on two interpenetrating face centred lattices of carbon atoms. According to Raman, these tetrahedra can point either way, so that there are 2×2 or four possible forms of diamond, two of which have tetrahedral and the other two, octahedral symmetry. In any actual specimen, these four structures can occur side by side or intermingled with each other and it is the variations in the nature and extent of the interpretation of the different structures that gives rise to the variations in the physical properties of diamond. A natural result of this theory is that the variations of different physical properties such as fluorescence, infra-red absorption and X-ray reflecting power must be definitely correlated to one another, and this has been definitely proved to be the case. Experimental evidence has also been forthcoming for the actual existence of the four varieties of diamond.

7 Infra-Red Studies

The radiations whose wavelengths are greater than those of visible light and less than those of the shortest radio waves constitute the so-called infra-red spectrum. They are of great interest

in relation to several subjects as for instance astro-physics, meteorology, thermodynamics and chemistry. Besides, infra-red rays have been used extensively during war time to communicate secret knowledge and also for "seeing in the dark" by means of these radiations which are emitted by all bodies to different extents.

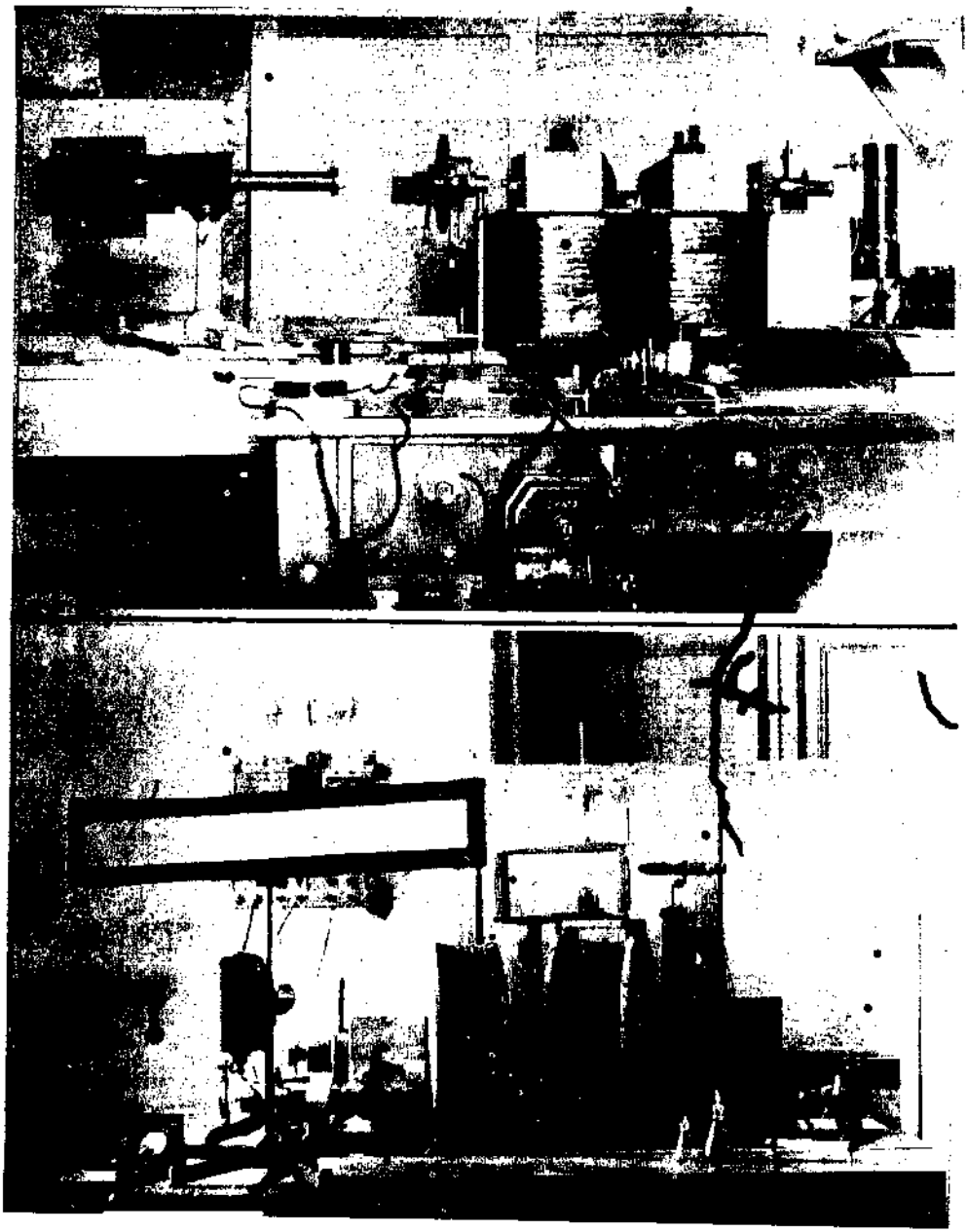
Great attention is being given in recent years in many laboratories in other countries to overcome difficulties of experimental work in the infra-red in view of the possibilities of making use of infra-red radiations for important applications, not the least, of which in the Defence Services. Hitherto, owing to lack of adequate equipment, only some pioneering work has been possible in this Institute. In spite of the many experimental difficulties, a small infra-red spectrometer was constructed some years ago in this Department and the absorption spectra of many crystals have been studied with it. These studies have shown that in the case of diamond the nature of the absorption curve is different with different specimens. The majority of diamonds exhibit a strong absorption between the regions 700 cm.$^{-1}$ and 1500 cm.$^{-1}$ while diamonds (not so common) do not show this absorption. There are some others which exhibit an absorption band of intermediate intensity. These striking differences in behaviour of different crystals of diamond formed the starting point for Raman's theory of the four allotropic forms of diamond. Further, the fact that the band exhibited by the majority of diamonds consists of a number of discrete absorption maxima lends support to the theory of crystal dynamics first put forward by Sir C. V. Raman. Other crystals like ammonium chloride, etc., have also been investigated using the small infra-red spectrometer. The results obtained are so encouraging that a large automatic recording infra-red spectrometer is at present being set up in this laboratory.

Exhibit No. 6 shows an arrangement to study the infrared spectrum of a crystal.

8. Crystal Magnetism

Iron, cobalt and nickel were for long believed to be the only substances that were affected by a magnet. It was not until 1845 that it was shown beyond all doubt by Faraday that the magnetic properties were not confined to the iron group of elements. He showed that all substances were magnetic to some degree, most

PLATE XVI



Two views of the Magnetic Laboratory

substances being repelled by a magnet while others like iron being attracted by it. The most fruitful researches in the history of magnetism after Faraday's discovery is that of P. Curie who designed a delicate balance (Exhibit No. 7) and measured the magnetic susceptibility of substances and its temperature variation. He found that while the susceptibility of diamagnetic substances was independent of temperature, that of the paramagnetics was inversely proportional to the absolute temperature.

It is well known that crystals exhibit magnetic anisotropy *i.e.*, they assume preferred orientations in a magnetic field. There has been great revival of interest in this particular branch of Physics in recent years as it has been possible to correlate the crystal structure with the magnetic anisotropy. Conversely, the measurement of the magnetic susceptibility and anisotropy are very useful in the determination of the structure of crystals.

In this laboratory, a great deal of attention has been given to the study of the magnetic properties of naturally occurring substances, such as Molluscan shells, mother of pearl, wood, cellulose, etc. The magnetic behaviour of a large number of minerals such as tourmaline, epidote, mica, tektite, augite, pyrite, etc., have also been studied. In many cases the magnetic properties have been correlated with other physical properties of the substances. For example, the large variations of susceptibility shown by iron pyrites crystals have been attributed to the stochiometric variations in the composition of the crystals.

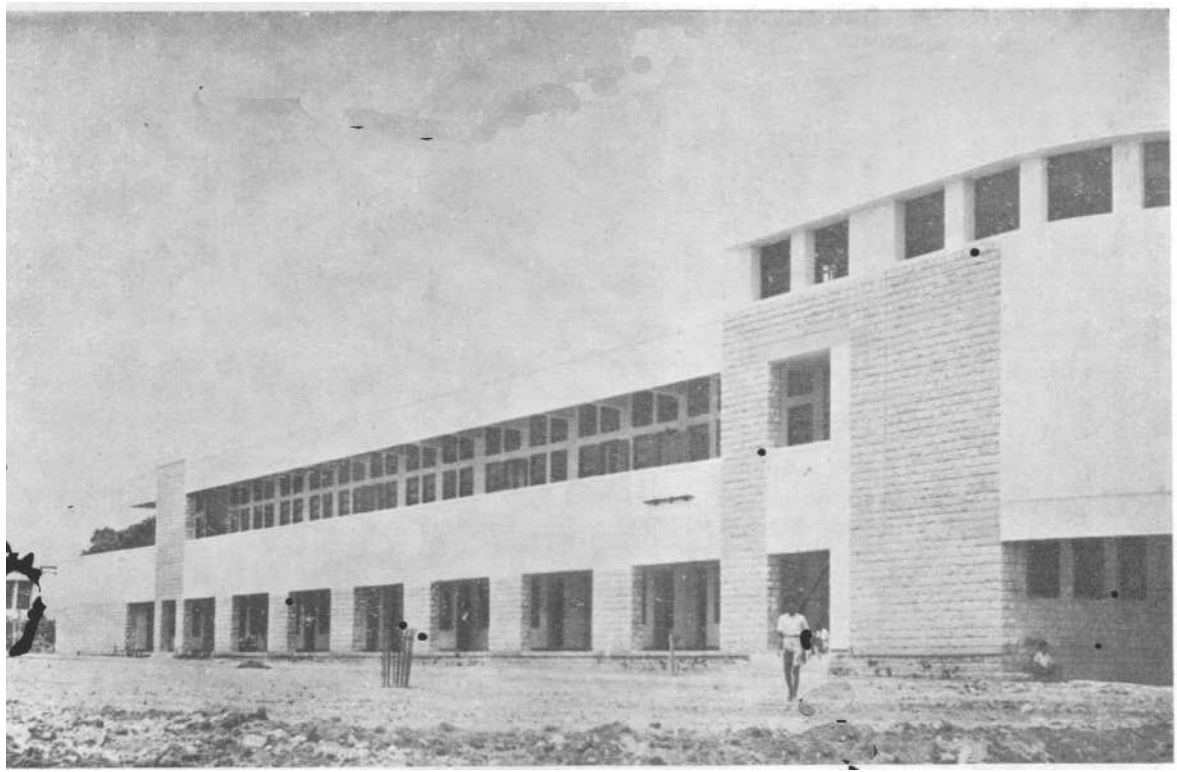
9. Faraday Effect

Faraday, after years of patient search, established that magnetic force and light were related to each other when he discovered the celebrated effect now called after him. The discovery was that the plane of polarisation of a beam of light is rotated while traversing a transparent medium placed in a magnetic field. The observation of this effect is essentially simple and is shown in Exhibit No. 8. A parallel beam of monochromatic light is polarised by a double field polariser and allowed to pass through a longitudinal hole of an electromagnet between the poles of which is placed a block of glass. The analyser which receives the light is rotated till the two halves of the field of view are of equal intensity. The switching on of the magnetic field makes

the intensities of the two halves different and the rotation that is necessary to restore the "matching point" is the Faraday rotation. The magnitude of the rotation is directly proportional to the field strength, the length of the column of substance and is also dependent on the wavelength of the light used. The measurement of the magneto-rotatory power has been of great use in resolving many controversies on the structure of organic compounds.

One of the many problems that has been puzzling the workers in this field is the fact that the experimental value of the Faraday effect is always less than the theoretical value predicted by Becquerel. This anomaly (defined as the ratio of the experimental to the theoretical values) is found to be constant over a wide range of wavelengths. The understanding of this anomaly was considered a matter of great importance and a systematic study was undertaken to elucidate its nature. Very accurate measurements of the magneto-optic constants were made in several cubic crystals such as diamond, zinc blende, rock-salt, sylivite, KBr, KI, to name only a few, over a wide range of wavelengths. Faraday effect measurements were also made in a series of optical glasses and substances in a state of solution to find out how the state of aggregation of matter affects the anomaly. The data so far obtained very clearly show that the nature of the electronic binding between atoms contributes greatly to the magnitude of the Faraday effect in a substance. The Faraday effect may now prove to be a very powerful tool in the determination of character of the binding between atoms in matter.

PLATE XIX



Building of the Metallurgy Department

METALLURGY

Metals and their alloys have always occupied a most vital position in the generation, transmission and distribution of all forms of power and, as far as can be foreseen, will continue to occupy this vital position. In the construction of the contemplated atomic piles for the harnessing of nuclear energy, in the provision of suitable materials to withstand the high temperatures and pressures obtaining in the jet engine, in the choice of the exact materials to withstand the corrosive action of acids and alkalies in the modern chemical plants, in these and in every other link in the power chain, metals and their alloys play a most vital rôle and it is hence only natural that the study of metals and alloys should occupy a most prominent part in our minds.

This Department has been started recently with the express object of promoting a comprehensive study of the properties and potential applicabilities of metals and their alloys. The chief aims of this Department are:—

(1) To provide advanced instruction at a post-graduate level in (*a*) metallurgical subjects covering the production, processing and testing of existing metals and alloys, both ferrous and non-ferrous; (*b*) subjects regarding the materials ancillary to the manufacture of metals and alloys, *viz.*, fuels, refractories, etc.

(2) To carry out advanced research, both fundamental as well as applied, with a view to discover (*a*) better methods of utilising and conserving existing metallurgical materials; and (*b*) new materials to replace existing ones.

A research and instruction laboratory must be very extensively equipped for carrying out investigations; this can be appreciated on a consideration of the items listed in the following schedule, many of which are already provided for in the equipment of this Department.

Data required for the complete examination of an alloy

(1) Chemical analysis.

(2) Metallographic examination.
Macrostructure.
Microstructure.
Grain Size.
Examination of inclusions (qualitative and quantitative)

(3) Physical properties.
Melting and freezing temperatures.
Critical points.
Specific gravity.
Specific heat.
Thermal conductivity.
Thermal expansion.
Electrical conductivity.
Thermoelectrical properties.
Electrochemical potential.
Magnetic properties.
X-ray analysis.

(4) Mechanical properties at normal temperatures.
Tensile strength (elastic limit, etc.).
Hardness.
Notched-bar impact.
Torsion.
Bend.
Fatigue.
Deformation.
Wear-resistance.

(5) Mechanical properties at elevated temperatures.
Stability.
Red hardness.
Creep properties.

(6) Mechanical properties at sub-normal temperatures.

(7) Resistance to corrosion and chemical attack (including corrosion fatigue).

(8) Resistance to scaling.

(9) Response to surface hardening.
Carburising.
Nitrogen hardening.

Effect of various heat treatments on the above properties.

Effect of various degrees of cold work on the above properties.

Effect of heat treatment after cold work.

Additional data required from the standpoint of industrial application

(1) Casting; feeding and production problems, heterogeneity.

(2) Hot working; applicability to manipulation by forging, drop stamping, rolling, etc.

(3) Heat treatment: response.

(4) Machinability: feeds, speeds and tool angles.

(5) Cold working: suitability to press work, stamping, punching, spinning, drawing, etc.

Facility for welding, for brazing, for hard soldering, and for soft soldering.

Response to pickling.

The Metallurgy Department in the Indian Institute of Science is being equipped to meet these aims. In the design of the buildings adequate space for carrying out researches by physical and mechanical testing methods has been provided on the ground floor with several largely separate units to accommodate the several different kinds of equipment. On the first floor, in addition to the lecture theatre and the administrative offices and stores, laboratories for research in Fuels, Electrometallurgy and Mineralogical Chemistry have been constructed. A general view of the departmental building is given in Plate XVII. In a separate wing of the building is accommodated a workshop, a foundry with facilities to melt and cast alloy steel and other special alloys, high temperature and induction furnaces, a small size rolling mill and other ancillary equipment.

Given below are the details of the exhibits on display in this Department:—

(1) Grinders and Polishers.

(2) Electro-polisher.

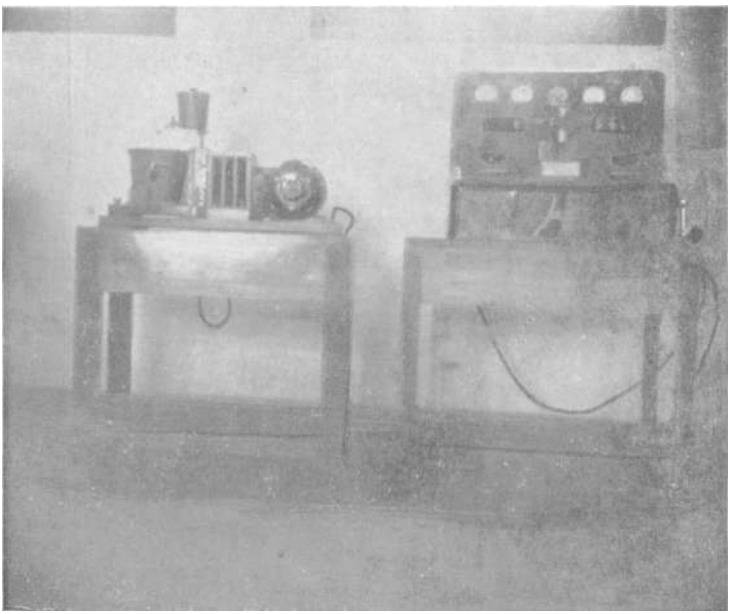
(3) Microscopes.

(4) Amsler and Avery Fatigue Testing Machines.

(5) Rockwell and Vickers Hardness Testing Machines.
(6) Magnetic Crack Detector.
(7) Tensometer.
(8) Thermal analysis.
(9) Dilatometer.
(10) Laboratory Flow Rator.
(11) Samples of reactive coke and liquid by-products.
(12) Collection of minerals.
(13) Plating baths (single metal).
(14) Plating bath (alloys).
(15) Electroforming.
(16) Electrolytic polishing.
(17) Anodizing.
(18) High Frequency furnace.
(19) Wild-Barfield furnace.
(20) Laboratory resistance furnace.

Physical Metallurgical Laboratories

In the ground floor are housed the various instruments and apparatus for the study by physical methods of the internal structure and constitution of metals and alloys and of the relation of the ultimate mechanical and physical properties of these materials to their internal structure. For these studies, which usually are included under the title of "Physical Metallurgy," the three methods of investigation, *viz.*, the thermal, the microscopical and the X-ray on the purely physical side and the methods of determination of the hardness and tensile strength on the purely mechanical side are of primary importance and provision has been made in the Physical Metallurgy section to carry out investigations by these methods. The other methods notably magnetic testing, electrical conductivity, fatigue and impact testing, though regarded as subsidiary to these former methods in their range of applicability, are valuable in themselves and sometimes indispensable and hence equipment based on these other methods has also been installed. Provision has also been made to instal an Electron Microscope, which carrying as it does the limit of resolution of the optical microscopes to a figure approaching about 25 Å units (25×10^{-8} cm.) forms the most recent tool in physical metallurgical research.



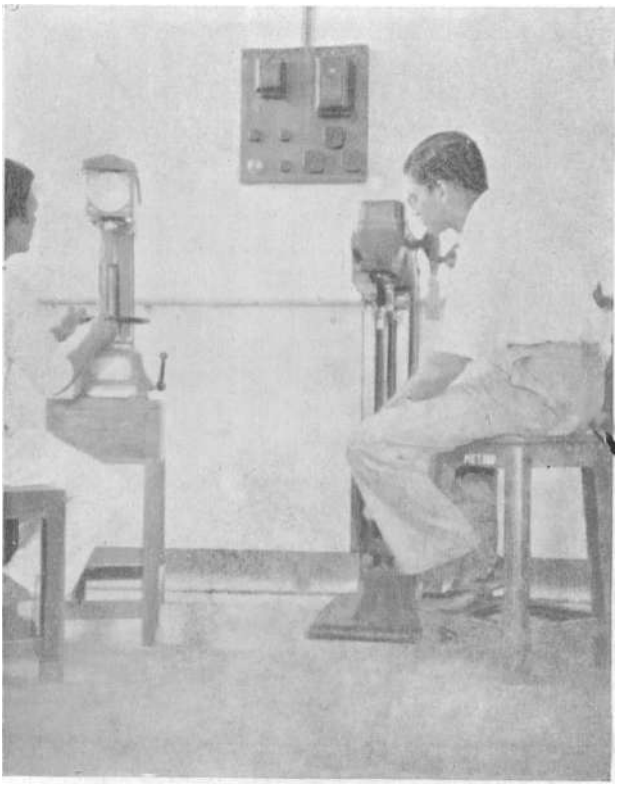
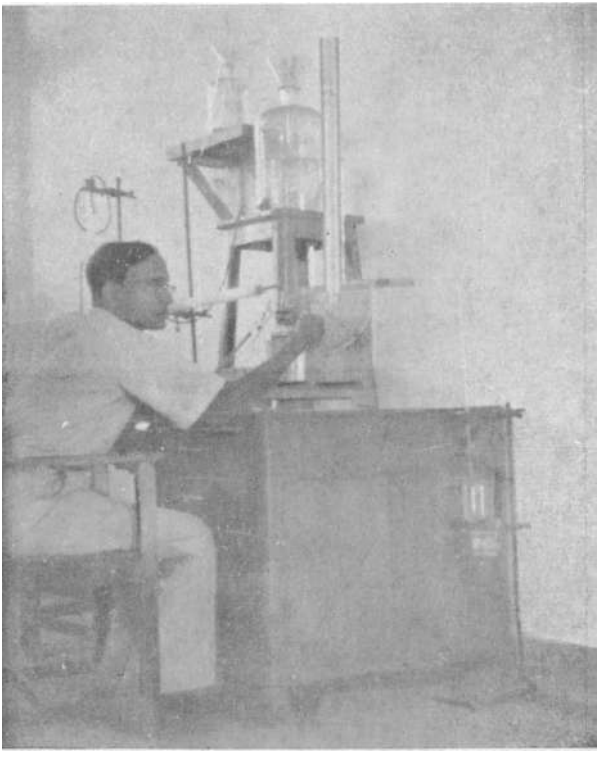


PLATE XVIII

Fatigue Testing Machines



Determining Flow Rate

The microscope is one of the most highly developed tools of the metallurgist, its utility and versatility not being exceeded even by the X-ray. Such factors as grain size, distribution of alloying constituents, condition of heat treatment and grain boundary phenomena may be accurately investigated. The specimens for microscopic examination have to be initially polished and etched. The polishing operations which are often very delicate are carried out by electrolytic processes or by mechanical means. Plate XVIII shows electrolytic and mechanical polishing machines. After polishing the specimens are suitably etched for the revelation of the internal structure. Specimens for polishing are often mounted in bakelite to handle them more easily A mounting press is in use in the laboratory.

There are four metallurgical microscopes in the laboratory—three of the bench variety and one of the inverted type. This last one, the Vicker's Projection Microscope is one of the finest types of metallurgical microscope, giving a range of magnification of from 2 to 4,400 diameters for both visual and photographic observation. A low power binocular metallurgical microscope on order and expected to be received shortly is included in this section.

For the carrying out of thermal analysis of metals and alloys and for carrying out experiments on the heat treatment of alloys the Vernier Potentiometer is one of the most accurate types of equipment available for enabling measurements of electromotive force to accuracies of a millionth volt to be made. Besides several galvanometers, other equipment of this section includes standard platinum thermocouples, a small Wild Barfield Muffle Furnace and other ancillary equipment.

Adequate provision has been made for carrying out metallurgical studies by the application of X-rays. X-ray diffraction, though relatively new, is the most valuable tool for fundamental investigation of the structure of metals and alloys beyond the range of the microscope. Through the examination and interpretation of the diffraction pattern produced when a narrow beam of X-rays is incident on a metal or an alloy and gets diffracted in various directions by the atomic planes of the latter, information on the metallurgical condition of the metal becomes available,

which cannot be obtained to the same degree by other research methods. The X-ray diffraction technique is used for the definition of the type and amount of preferred orientation of grains in hot and cold worked metals, for the study of recrystallization taking place after cold working and for the determination of the presence of residual stresses. Precise lattice measurements at low as well as high temperatures are possible which permit a thorough investigation of solid solution and precipitation phenomena. It is intended to instal a most modern type of X-ray diffraction apparatus together with all necessary auxiliary equipment, as also an X-ray set for the generation of hard rays for radiographic testing of metals.

Other chief items of equipment in the Physical Measurements Laboratory are the Magnetic Crack Detector and the Dilatometric apparatus for the accurate measurements of specific volume, an apparatus developed by a member of staff of this Department, a double beam cathode-ray oscillograph, a Beat Frequency Oscillator and other electronic equipment.

The mechanical testing section, at present located in the Physical Measurements Laboratory, is, as mentioned earlier, a most essential requisite for a metallurgical laboratory and this Department is well equipped to carry out a wide variety of mechanical tests on metals and alloys.

The Standard hardness testing machines—Vickers, Brinell and Rockwell (Plate XVIII)—are all used in the laboratory and a special micro-hardness tester to be used in conjunction with the Vickers Projection Microscope for determining the hardness of microscopic constituents and measuring the bearing qualities of metals, is to be obtained shortly. A 20-ton Amsler Universal Testing Machine is being installed to carry out all routine tests on the tensile, compression and shear properties of metals, while an Izod Impact Testing Machine to determine the resistance of alloys to sudden stresses and a Hounsfield Tensometer to determine the mechaninal properties of extremely small specimens have also been obtained and installed. The study of the fatigue of metals—of extreme significance in the performance of propeller blades, connecting rods, pistons and other similarly highly stressed parts—has resulted in the continuous improvement of

manufacturing methods and of alloy composition to a point where, today, a fatigue failure in actual operation is the exception. The laboratory is equipped with two fatigue testing machines (Plate XIX) (one by Avery, one by Amsler) for testing materials under conditions of alternating stress at high speeds. The properties of experimental alloys can be studied in detail in any wrought or cast form, and special equipment is used for testing under conditions similar to those encountered in actual service.

Fuels Laboratory

Production of reactive coke by low temperature carbonization

Low temperature carbonization involves partial destructive distillation of coal between 450° C. and 600° C. whereby a solid smokeless fuel is produced of uniform composition and high calorific value. The fuel is readily ignited on open grate without blast and is highly reactive towards CO_2 and steam thereby imparting the quality of an ideal fuel for the production of water gas. This property is of considerable importance in the complete gasification process to produce synthesis-gas for the manufacture of liquid fuels by Fischer-Tropsch process on the one hand, and on the other, to produce mixed gas for ammonia synthesis. In addition to the very useful coke that is produced by low temperature carbonization, large amounts of tar can be obtained as by-product which on distillation and subsequent cracking and hydrogenation would yield high-octane gasoline, motor fuels, and other petroleum-like products.

By the low temperature process, one ton of coal yields nearly 80% of smokeless fuel, *i.e.*, 16 cwts. per ton. The yield of crude tar is approximately 15 gallons per ton of coal treated and in addition to this, about 2 gallons of 'light hydrocarbon oils' are generally obtained as stripped benzine from the rich gases given off during distillation. Not less than 5,000 c.ft. of gas of a very high calorific value are obtained per ton of coal.

By the straight distillation of tar, a fraction predominant in light paraffinic hydrocarbons comparable to commercial petroleum ether boiling between 50° and 80° C., a petrolic fraction boiling between 80° and 135° C., a kerosine fraction boiling between 135° and 230° C. and a gas oil fraction boiling between 230° and 350° C.

are obtained. The phenols from each fraction are separated by neutralisation and subsequent acidification.

More reactive cokes are obtained by the addition of small amounts of substances like sodium carbonate, calcium acetate, etc., and then carbonising at a low temperature. The effect of addition of the substances on the reactivity of resultant coke and on the ratio of neutral oil-phenol found in the tar is under investigation.

Some of the products are exhibited.

MINERALOGICAL AND ORE DRESSING LABORATORY

Provision has been made for the beneficiation of a number of low grade ores available in India, and this is under investigation using flotation and heavy media processes.

The following is the list of collection of some of the important minerals found in the Mysore State:—

Name of the Mineral	*Source*	*District*
Bauxite	Kemmangundi	Kadur Dist.
Garnet	Hassan	Hassan Dist.
Hæmatite	Bababudan Hills	Kadur Dist.
Magnesite	Mavinahalli	Mysore Dist.
Kyanite	Holenarasipur	Hassan Dist.
Hypersthene	Pakawara (Kaivara)	
Psilomelance	Kumsi Mines	Shimoga Dist.
Bauxite (Silecious)	Shivaganga	Tumkur Dist.
Beryl	Yediur	Bangalore Dist.
Graphite	Ganachapur	Kolar Dist.
Staurolite	Holenarasipur	Hassan Dist.
Limonite	Bababudan Hills	Kadur Dist.
Pyrites	Ingaladahalli	Chitaldrug Dist.
Muscovite Mica	Kabbur	Hassan Dist.
Asbestos	Idegondana Halli	Hassan Dist.
Malachite	Somanahalli	Mysore Dist.
Chromite	Byrapur	Hassan Dist.
Felspar	Settyhalli	Bangalore Dist.
Galena	Gonur	Chitaldrug Dist.
Corundum	Maddur	Mandya Dist.
Pyrolusite		Chitaldrug Dist.

Garnet	Holenarasipur	Hassan Dist.
Kaoline	Bageshpur	Hassan Dist.
Garnet	Saidapuram	Nellore (Mysore State).

Collection of minerals from other parts of India

Magnetite	Manganese Ore
Corundum bearing Rock	Asbestos
Red Ochre	Pegmatite
Pyrites	Celestine
Columbite Tantalite	Feldspar
Fluoride	Garnet Sand
Yellow Ochre	Quartz
Galena	Hæmatite Quartzite
Marble	Talc
Muscovite	Phosphatic Nodule
Sandstone	Tourmaline in Quartz
Zircon	Pyrites in Quartz
Calcite	Microcline Felspar
Sulphur	Samarskite
Magnesite	Microcline
Beryl	Ilmenite
Corundum	Rutile
Gypsum	Ceylon Graphite
Kyanite	Manganese Ore (Central Provinces).
Malachite	
Pumice	

ELECTROMETALLURGY SECTION

Electrometallurgy covers, broadly, the various aspects of the utilisation of electrical energy either in the form of heat or for electrolytic decomposition.

Electric furnaces of various types right from the electric toaster, domestic hot plate to the large industrial arc furnaces for production of alloy steels are examples of conversion of electrical energy into heat. Other fields of industrial applications are the induction melting for production of special steels, and induction heating in heat treatment.

Production, refining, and recovery of various metals from their ores by electrolysis, either of aqueous solutions or fused electrolytes, is another section of electrometallurgy. Outstanding examples of this are the production of electrolytic copper, a strategic material in electrical industry, and electrolytic aluminum required in aircraft industry. Improvements in existing methods of manufacture of various metals and alloys and also production and study of the qualities of metals form an important field of research for the electrometallurgist. A scheme for the production of beryllium and its alloys to be investigated in the Department of Metallurgy has been sanctioned by the Council of Scientific and Industrial Research, New Delhi.

Two sections, *viz.*, Electro-thermal and Electrolytic, are exhibited. In one room an experimental Ajax Northrup High Frequency Furnace of 20 KW capacity is located. It is suitable for production of alloy steels, melting of precious metals like platinum and gold. The temperature that can be obtained is limited only by the temperature the refractory can withstand. It is usually capable of withstanding 2,000 ° C. The principle is the generation of heat in the body of the metal by the eddy currents induced in it by the high-frequency current in the primary coil. The metal forms a short-circuited secondary of an air core transformer. The frequencies employed are of the order of 10,000–20,000 cycles per second.

A wild-Barfield resistor furnace is also located in the same room. It is of 6 KW capacity suitable for operation on 400 volts 3 phase 50 cycles. The upper limit of temperature for prolonged life of elements, which are of re-crystallized silicon carbide and are capable of ready replacement, is 1,200° C. A wide range of temperatures is possible with the aid of the tap switch. It is suitable for heat treatment of metallurgical specimens and such other applications where a steady uniform temperature is required.

The other room is devoted to electrochemical experiments. Electroplating is an important section of electrochemistry in which aqueous and non-aqueous electrolytes are employed for depositing thin uniform and bright coatings of metals like nickel and chromium either for decorative purposes or for protection on metals like iron, copper, etc. The various stages in the treatment of

rusted steel for production of a polished chromium-plated specimen are shown. These consist of cleaning, polishing, various platings of copper, nickel, chromium and final finish.

An example of alloy plating where two or more metals can be deposited at the same time is shown as an exhibit. Speculum plating is a unique achievement in this. It is reputed to be better than chromium or silver in its reflective power. It is an alloy plate containing 40–50 per cent. tin and the rest copper.

Electro-forming is another section of electrodeposition. A replica of any object can be obtained by the process. The various steps are shown. Starting from the moulding metal we have the mould, the plated specimens, and finally the finished specimen.

Anodizing is a specialized process of producing thick porous coating of aluminum oxide on aluminum. The porous coating is capable of adsorbing and retaining light-fast dyes, and a special application of this is in the table decoration. Some examples of anodized and dyed specimens are exhibited.

INTERNAL COMBUSTION ENGINEERING

Introduction

The phenomenal advance of the science and practice of internal combustion engineering shows no sign of abatement: reciprocating engines are still being designed to meet new requirements and the advent of the gas-turbine presents a new series of problems to be solved in this field of endeavour.

Internal combustion engines are distinguished as being relatively compact, efficient and light-weight prime-movers adaptable in design for use in land, air and sea transport and for stationary purpose. Increasing use of internal combustion engines is thus bound to be a concomitant of industrial development of this country.

It is clear, therefore, that there will be a growing demand in India for properly qualified engineers, well acquainted with the fundamentals of design, development, inspection, testing, production, operation and maintenance of such engines, which must be met before any real degree of independence is attained in this sphere of activity.

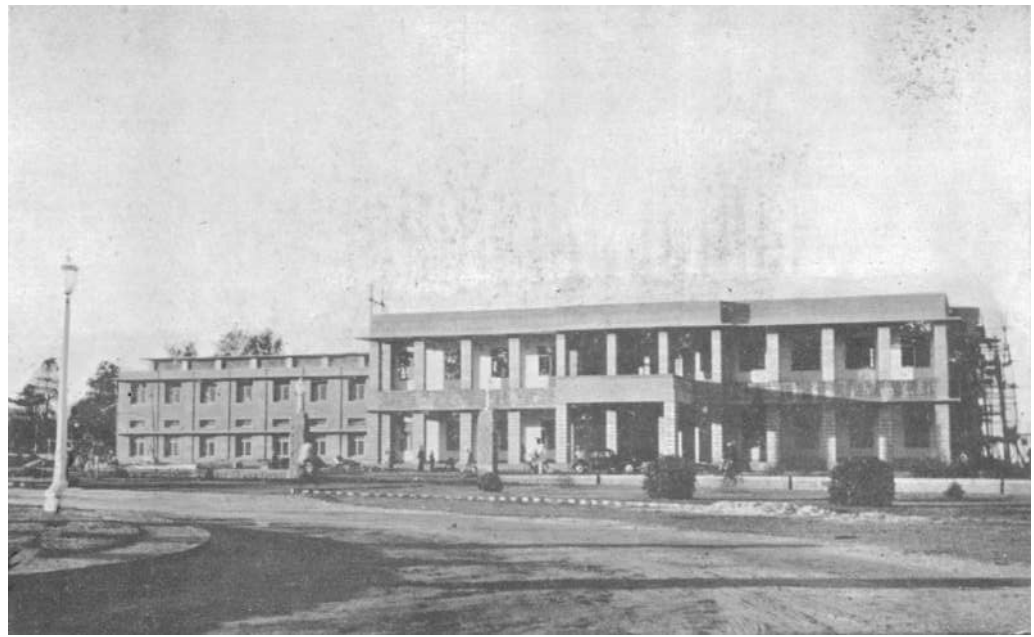
The building up of the Department of Internal Combustion Engineering at the Indian Institute of Science was begun (none too early) some three years ago with the express object of affording the fullest possible facilities to:

(*a*) post-graduate mechanical engineering students of distinction for advanced study of the fundamentals of the subject in relation to engine design, development, etc., in the several fields of application;

(*b*) research staff and scholars for doing researches of a long-range character.

The main laboratory contains apparatus for demonstration of fundamental principles; also, to assist advanced instruction under the first category by establishing close association of theory and application, there are representative engines, engine components and accessories distributed between the main laboratory and an exhibition room. Treatment of the subject as an applied

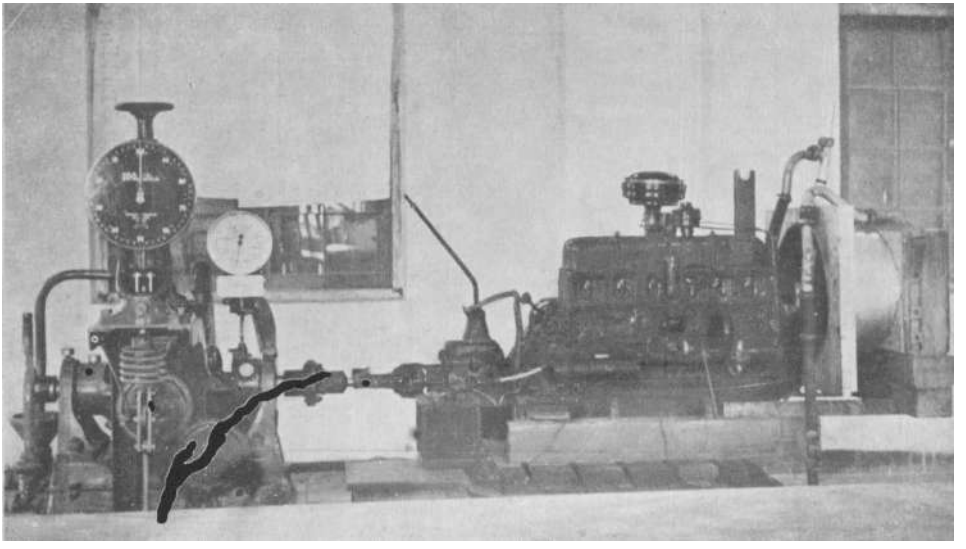
PLATE XX



Building of the I. C. E. Department

PLATE XXI

Interior view of the I. C. E. Laboratory



Lorry Engine Coupled to Froude Brake

science provides a basis for exploring and giving advice concerning new possibilities in design and practice: whereas the latter should not be followed slavishly, there must be knowledge of successful practice.

The main laboratory is being equipped for conducting experimental work under the second category: particulars of equipment are given later. An interior view of this fine-laboratory is shown in Plate XXI.

Practical study is linked to factory experience in premier industrial establishments such as Hindustan Aircraft, Kirloskar's and Cooper Engineering Works.

Fundamentals of the subject can be studied very fully in the Department, experience of designing and of experimental research can be obtained and a large degree of acquaintance with practice can be achieved; experience abroad can be assimilated better subsequently with an adequate foundation laid.

Association with Proposed National I.C.E. Research Laboratory

Although the testing of engines, fuels and lubricants is not itself a function of the Department nor is short-range developmental work, such work has important instructional value and will be engaged in partly on this account and also partly as an interim measure pending the establishment of a National I.C. Research Laboratory (under the auspices of the Council of Scientific and Industrial Research) wherein official testing of I.C. engines manufactured in India may be carried out, development of such engines assisted, and some special investigations pursued.

The scope for original long-range research on Reciprocating I.C. Engines is limited by the extensive study already made of such engines. However, there have been important developments in techniques for making special measurements of such things as vibrations, stresses, pressures and temperatures and the introduction and application of these techniques, *plus* the developmental and test work mentioned, will involve no little departmental work for some time to come. A variety of problems also arises for research such as standardization of vegetable oils as lubricants, particularly castor oil which forms such a rich source in the country, and its behaviour at low temperatures.

From the outset it has been considered that the Gas Turbine in its various forms offers much greater scope for long-range research as it is a more recent development. The Department is not, however, equipped to undertake such research as it would over-tax its resources. Work in this domain is to be undertaken with substantial outside assistance; the I.C.E. Committee of the C.S.I.R. have made recommendations accordingly and the C.S.I.R. have given administrative sanction in support to the extent of Rs. 2 lakhs non-recurring and Rs. 25,000 recurring. More explicit proposals are now in preparation to submit for financial sanction. It may be appropriate to mention here that although enormous expenditure will be necessary for conducting gas turbine research and development on the scale prevailing in the U.K. and in the U.S.A., if a start is made now on the extremely modest scale proposed, there will come into being a staff capable of giving expert advice to the Government of India on Gas Turbine matters and such staff may form a nucleus for implementing any larger schemes undertaken. The recent acquisition of a number of jet fighters by the Royal Indian Air Force underlines the necessity for a team of gas-turbine research workers. At the same time, the existence of a modest establishment should not be permitted to obscure greater needs in this respect.

If the National I.C. Research Laboratory were to be located adjacent to the I.C.E. Department of the Indian Institute of Science, the two supplementary activities could be given a very desirable close relationship. In such case, the Gas Turbine Research would conveniently be conducted in the National I.C. Research Laboratory as a separate part of its work.

This proposal fits in well with the siting of the I.C.E. Department Buildings as these comprise a main block with the laboratory attached as one wing with corresponding space for another wing on the other side. The main block has, in fact, been constructed to suit the addition of a second wing and it was designed to take a second storey when required.

I.C.E. Department Buildings and Equipment

The foregoing will serve to give a background and setting to the I.C.E. Department itself, concerning which some particulars will now be given.

The buildings to which reference has been made are practically completed. The main block has a plinth 120 feet by 60 feet and accommodates an Exhibition Room for typical engines and components, a Drawing Office, a Lecture Theatre, Professor's Laboratory, Class Rooms and Offices. It is connected at one end to the laboratory (which is set back in consideration of noise) with a common floor level both upstairs and down to facilitate transfer of apparatus from one building to the other.

The plinth of the laboratory is 134 feet by 60 feet and the upstairs floor comprises a balcony which extends round the interior of the building. The central portion of the building is spanned by 3 ton crane, located near the roof, which can travel the whole length. The balcony is adapted for light experimental sets, pilot workshop, fitting shop, and stores, and underneath there are bays for accommodating engine-testing sets. Provision is made for conducting vibrational observations in a dark room and some special apparatus is being made for conducting experiments on the torsional stiffness of such engine components as crankshafts, propeller shafts, and reduction gearing.

A Froude hydraulic absorption dynamometer is installed which, when coupled to a swinging-field electric dynamometer-motor, will enable tests to be made on engines up to 250 brake horsepower. In connection with this and other testing plant, a water circulation system is provided coupled to roof tanks and to a cooling fountain.

A Broomwade two-stage air-compressor-set with a swinging-field electric dynamomotor is installed which will supply the laboratory with compressed air at 200 lb./sq. inch pressure.

A Ruston-Hornsby 15 b.h.p. horizontal Diesel engine with Prony brake is being installed. There is a Rolls Royce Griffon engine installed in a Spitfire, and steps have been taken to procure a Whittle jet-engine.

An important item of equipment, yet to come as delivery has been much delayed, is a Ricardo E6 single-cylinder variable-compression unit. This will have alternative cylinder-heads whereby it can be run either as a petrol engine or as a Diesel engine. The compression ratio may be varied while the engine

is running and the unit is admirably adapted for studying the effects of compression ratio changes on the behaviour of the engine at different settings and with different fuels.

For instantaneous recording of pressure changes, or of vibrational movements or strains, an electronic set has been installed in a special trolley for convenience of location. This is of capacity type and, by means of suitable pick-up units, it can be used to show such changes on a cathode-ray screen and to record them on a drum camera. At present it is arranged to record indicator diagrams from a 5 b.h.p. petrol engine coupled to an electric dynamometer.

Vibrations of various kinds present serious problems in engine and propeller design, and in the design of blades and other components of gas turbines, as they can give rise to very destructive fatigue failures. The electronic apparatus may be used for investigating such problems. In collaboration with the Metallurgy Department of the Institute, a number of investigations on the behaviour of various alloy materials in this respect is possible.

To demonstrate various ways in which propeller and turbine blades may vibrate, a piece of apparatus has been constructed in the departmental workshop whereby a long flat strip of steel is made to vibrate simultaneously edgewise and flatwise and is viewed by intermittent light from a Stroboflash electric lamp (see Plate XXII). Also, to demonstrate some forms of forced vibration, an arrangement of double pendulum has been set up. Further demonstrations are being arranged relating to vibration-fatigue tests on turbine blades.

A Chevrolet lorry engine of 100 b.h.p. has been coupled to the Froude brake and some preliminary tests have been made with a cooling system embodying a Spitfire radiator coupled to the engine. A photograph of this plant is shown in Plate XXI.

A Department so new is not in a position to report much research work done. However, on the basis of theory alone, a novel form of electric generator has been designed and made which is adapted for running at very high speeds. This generator is being coupled to the Chevrolet engine (through step-up gearing) for trial. It may prove to have application in conjunction with

PLATE XXII

Vibration of Steel Strip

Left : Edgewise vibration. Right : Flapping vibration

gas and other turbines but, in any case, it provides to be a useful piece of equipment in the laboratory as a high-speed absorption dynamometer and for producing alternating current of any desired frequency.

Provision is being made for a Fuel Section and, in relation to this, a C.F.R. supercharged single-cylinder unit is being obtained and Hartridge Fuel-Test and Injector Nozzle Benches.

Provision is being made also for an Ignition Section and for this a Crypton Ignition Test-Bench and a Spark-plug Test-Bench are being obtained.

It is projected to examine the behaviour of different Diesel fuels in small stationary engines and to make some investigations into the behaviour of Castor oil and Castor-based oil as a lubricant.

It is the policy of the Department to maintain close contact with firms and establishments concerned with the manufacture, development and use of internal combustion engines in India.

Plate XX shows a view of the impressive front of the I.C.E. Departmental Buildings.

ELECTRICAL COMMUNICATION ENGINEERING

Instruction and research in electrical communication engineering were first started at the Institute about 25 years ago by the late Prof. J. K. Catterson-Smith when he succeeded the late Dr. A. Hay in 1923 as Professor of Electrical Technology. The Institute is the first institution in India to introduce this subject and is the leading centre in the country for study and research in it. This position is due to the vision and leadership of Prof. Catterson-Smith and of his successors, Prof. F. N. Mowdawalla and Prof. K. Aston.

Diploma Course

The Department runs a course in electrical communication engineering which is of three years duration for graduates in mathematics and physics, and leads to the Diploma of the Institute in the subject. For those who have taken the Bachelor of Engineering (B.E.) degree in electrical engineering of a recognised university, the course is of only one year and they join the final year directly.

The standard of instruction is at least that of a university degree in the subject, and only those who possess the minimum qualification of a first class B.Sc. degree in physics or mathematics are considered for admission. To ensure individual attention and to maintain the highest possible standard of work and aims, not more than 15 students are at present admitted to the course every year. Because the Institute is a national organization and because also of the heavy pressure for admission every year, only the cream of Indian youth get selected.

The first two years of the course are almost exclusively devoted to the study of the principles of civil, mechanical and electrical engineering which is the indispensable foundation on which alone any worthwhile course in electrical communication can be built up. The third year is devoted entirely to electrical communication subjects. The course includes a study of scientific German and French and lectures on industrial economics and psychology.

It is obligatory for the students to undergo practical training during the summer vacations in recognized commercial engineering concerns for a total of 32 weeks spread over the three years, 8 weeks at the end of the first, 12 weeks at the end of the second and 12 weeks at the end of the third year. The final year students are encouraged to engage themselves for a part of their time on some work of their own outside the syllabus, either by assisting a member of the staff in his investigations or in developing and constructing some new apparatus. In this and other ways, an attempt is made to develop in them initiative and the spirit of research.

At the weekly meetings of the Electrical Engineering Society and of the colloquia, the students are encouraged to speak on subjects which they may have studied or worked on in the laboratory. The object is to develop in the students the ability to express themselves before both technical and non-technical audiences.

Electrical communication students of the Institute have always been in demand for employment. This situation is due to the development of broadcasting and other telecommunication services in India during the last decade, the high calibre of the students themselves and the limited number of students admitted to the course so that the members of the staff can devote individual attention to each student. Considerable numbers of the communication students of the Institute are to be found in all ranks from chief engineer downwards in the All-India Radio, the Directorate-General of Civil Aviation, the Overseas Communication Service and the Posts and Telegraphs Department of the Government of India, etc. During the last war, a number of our students entered the commissioned ranks of the armed forces. Most of them went into the signals and radar branches of the Indian Air Force and have served in different theatres including the forward areas. Almost all the Indian officers in the radar branch of the Indian Air Force were past students of the Institute in electrical communication. Reports go to show that they gave a good account of themselves both by their technical knowledge and ability and also by their character and behaviour as officers of the armed forces.

Research and Development

While the conduct of the three years diploma course is the primary function of the Department, research and development work has always formed an integral part of the daily activities of its staff and students. Reports on these investigations have been published from time to time in leading scientific and professional periodicals in India, England, Germany and the U.S.A.

The subjects of investigation have varied from time to time depending on the interests and inclinations of individual workers and arising from their work in the laboratory and the lecture room. Due to this reason and due also to the absence in India of an industry manufacturing telecommunication equipment and materials, such investigations have been on the whole on non-industrial subjects.

In radio, the subjects that have attracted attention have been radio wave propagation over the ground and through the ionosphere, atmospherics, short wave antennas and directive arrays, properties of circuits, high frequency measurements and ultra-high frequency technique.

In wire communication, the properties of filters and carrier communication attracted attention in the earlier days. Latterly, questions relating to automatic telephony and the application of the principles of automatic telephony in other directions have been taken up.

Though lectures on studio acoustics have always formed part of the diploma course, it is only since 1943 that facilities have been built up for the laboratory work of the students and for experimental investigation in the subject. A room in the laboratory has been converted into a reverberation chamber and this is used for determining the properties of acoustical materials. But the existing facilities are neither adequate nor satisfactory. An up-to-date well equipped laboratory is very necessary to meet present day needs of instruction and research in the subject.

Brief details are given below of the research and development work that has been carried out during recent years as also of the work in progress at present. The latter covers wire communication, electro-acoustics, ultra-short wave technique, wave propagation, pulse modulation, etc.

In many of these cases, the apparatus will be on view as far as possible under their normal working conditions during the days of the Exhibition.

Developments of the Future

New Building.—An up-to-date well equipped laboratory building expressly designed to meet the present-day requirements of instruction and research in electrical communication engineering has been a crying need for many years. For lack of such a building, the work of the students and of research has been hampered at every turn. It is therefore a great thing for the Department that thanks to a grant from the Central Government, the construction of a new building has been sanctioned and that the foundation stone for it will be laid by the Prime Minister of India on 27th December 1948. A happier and more auspicious start could not be desired and it is to be hoped that the present hopes and expectations that the new building may quickly become the seat of a vigorous and flourishing school of advanced instruction and research in electrical communication engineering will be amply fulfilled.

A new laboratory building for electro-acoustics also is very necessary, particularly because there is not in the whole country a suitably equipped up-to-date acoustical laboratory.

Radar.—Instruction and research in radar should be started at the Institute without delay. This is an urgent matter not only on account of its inherent scientific interest, but also because of its vital importance to defence. The perfection of radar from its elementary beginnings before the last war to the finished offensive and defensive weapon which played so amazing a part in the prosecution of the war and in the way the war ended forms one of the most striking developments in the history of the progress of science and engineering. Its role during the war, the plans that are being made in the U.S.A. and elsewhere to develop a radar screen to protect the country against attack and the immense financial outlay contemplated for the execution of these plans should be a standing warning to the statesmen, military leaders and scientists and engineers in India. Outside the armed forces, there is not in the whole country a single institution with a programme of instruction and research in radar. This is a serious

matter and it should be the privilege and duty of the Institute to take on this work in co-operation with the armed services and the other organisations interested in the matter. It is essential to do so from every point of view.

Manufacture of electronic tubes.—In spite of the growth of broadcasting in India in recent years, and of the different telecommunication services, no industry exists in India to manufacture telegraph, telephone and radio equipment and parts. The electronic tube is the most vital part of any communication apparatus and there are in India at present some 2,50,000 broadcast receivers. It is therefore high time that the Institute should provide itself with facilities for study and research in the manufacture of electronic tubes, so that there will be a body of young men who will possess some knowledge and experience of this important subject. This is all the more important as there are signs that some of the Indian industrialists in co-operation with manufacturers abroad are intending to develop receiver assembly and receiver manufacture.

Pulse and microwave technique and pulse modulation.—This too is a field which ought to be taken up in right earnest and which is developing rapidly thanks to intensive research in France, Great Britain and the U.S.A. This subject is allied to radar in several ways as also to television. Pulse communication on micro-waves may well develop into a most important and widespread system of countrywide communication. The Institute must have a good microwave laboratory.

It does not appear likely that television will make its appearance in India as a public service for a good few years to come. Even so, the subject should be studied in India and there should be men in the country who are actively at work in the field and contribute to the development of the subject. There cannot be a better place than the Institute to start such work.

Wave propagation.—An understanding of wave propagation is the basis of radio communication. The work that is at present being conducted should be extended and intensified to cover ultra-short waves and micro-waves.

Wire Communication

A device for the control of road traffic lights.—There are a number of systems in different parts of the world for the control

of road traffic lights. In the circuit that has been developed at the Institute, the switching technique used in telephony is employed for the control, either manually or by automatic methods, of traffic lights. In large cities where traffic is heavy, its control is effected by signalling with three lights, green, red and yellow. The green light gives the "go" signal, the red light the "stop" signal and the green-yellow or the red-yellow light the transition signal. These lights are switched on in a proper sequence and with definite durations.

The present circuit uses the usual telephone components, such as relays and a rotary switch, and allows both manual and automatic signalling. The manual signalling is done by operating a key with only two positions and is fool-proof. No mistake is possible in the sequence of signals.

The automatic control of the traffic lights is effected by the rotary switch which is brought into operation by turning on a switch. The rotary switch goes on giving the signals in their proper sequence and predetermined durations until it is switched off, when the wipers of the rotary switch go back to their positions of rest. According to the magnitude of the traffic, two fixed speeds of automatic signalling are incorporated in the circuit. The speeds are varied electrically by means of a second switch. Should the rotary switch get stuck at any position due to some fault, the signalling can be continued manually without any change in the sequence.

Uniselector as final selector.—In private automatic telephone exchanges having a small number of subscribers, uniselectors are often used as the final selector. A final selector circuit with a 25-point uniselector of the A.T.M. type has been developed in which the discrimination of the dialled digits as well as the homing of the selector are carried out by the same contact bank.

Calling signals in railway stations.—An investigation now in progress deals with the question of the application of the principles of automatic telephony to the control of calling signals in railway stations. In a big railway station, important officers, such as the station master, are often called on the telephone; but owing to the nature of their duties, they are, more often than not, outside their rooms. As these calls relate to the railway

traffic, it is essential that they must reach the particular officer wherever he may be at the moment. For this purpose the proposal is to set up signalling devices at appropriate places at a number of selected positions of the station with which to draw the attention of these important officers. An automatic telephone system is being developed on these lines so that the called person can receive the incoming call from the nearest telephone set.

It is also hoped to take up in due course the following investigations: (*a*) selective ringing by means of neon lamps on party lines, (*b*) the design of a selector relay, (*c*) reduction in the number of relays in the subscriber's line circuit in automatic telephony, (*d*) the design of a special test circuit for the high speed motor-uniselector that would allow its speed to be increased, (*e*) the development of an arrangement for automatic multimetering on trunk lines that are worked full automatic, and (*f*) the development of a key sender with vacuum tubes.

Electro-Acoustics

Reverberation-time Meter.—This apparatus has been developed to trace point by point the curve of the decay of sound in a chamber, and measures sound intensities (or equivalent loudness) over the range 30 db to 130 db above the minimum audibility level. It conforms generally to the standards laid down by the American Standards Association and has a pentode-diode type of indicating device. To render the indications of the instrument proportional to time, an electronic circuit arrangement has been devised to linearise the voltage developed across the condenser in a C-R circuit. This point-by-point method of tracing the sound decay curve is still used in a number of acoustical laboratories.

Reverberograph.—This is an electronic method of recording power level in the form of a curve delineated on the screen of a cathode-ray oscillograph tube. It has been specially developed to obtain in one single operation the reverberation characteristics of a room ranging in size from a small studio to a large auditorium. It is a portable apparatus which does not involve any moving mechanical parts; it is found to be very convenient in practice in the acoustical treatment of a room to secure a desired reverbera-

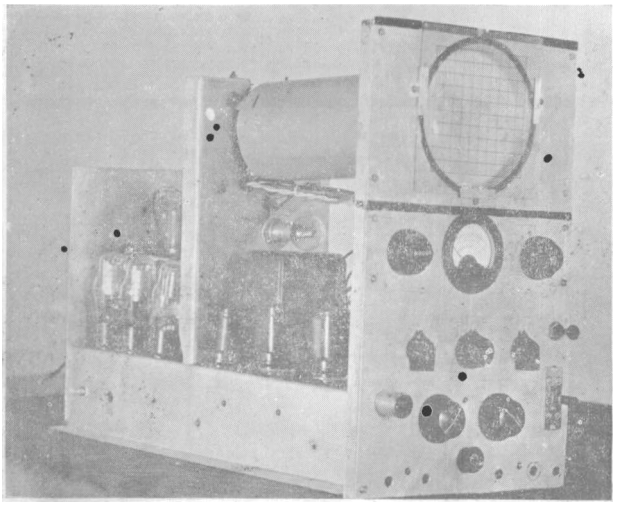


FIG. 1.

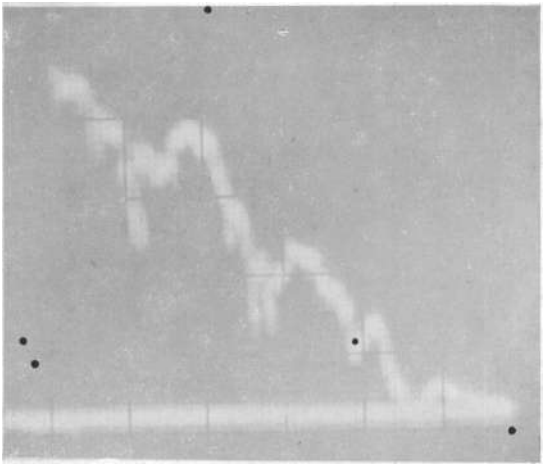


FIG. 2.

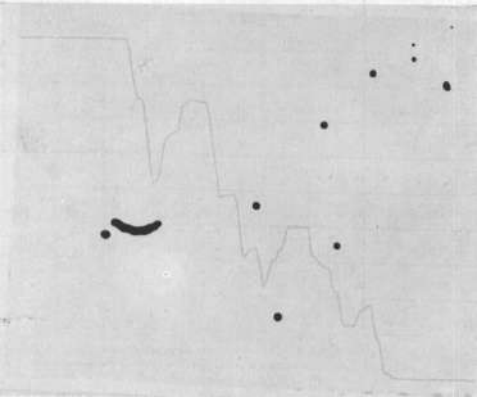


FIG. 3.

PLATE XXIV

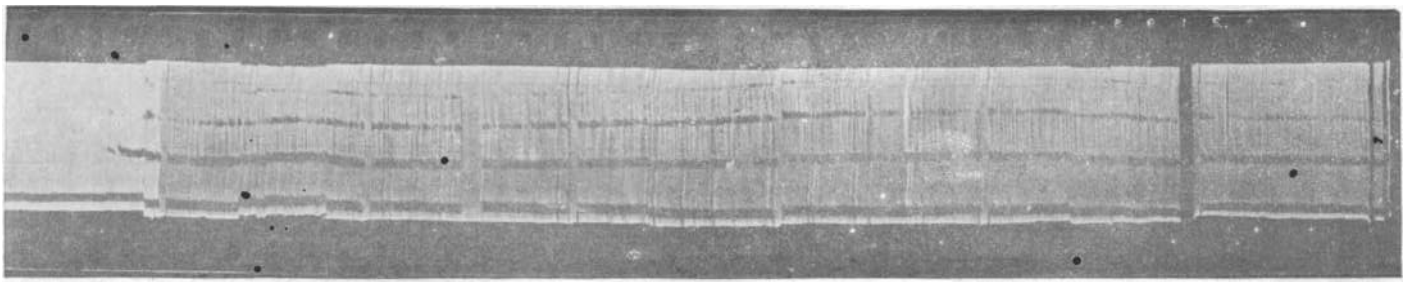


FIG. 4.

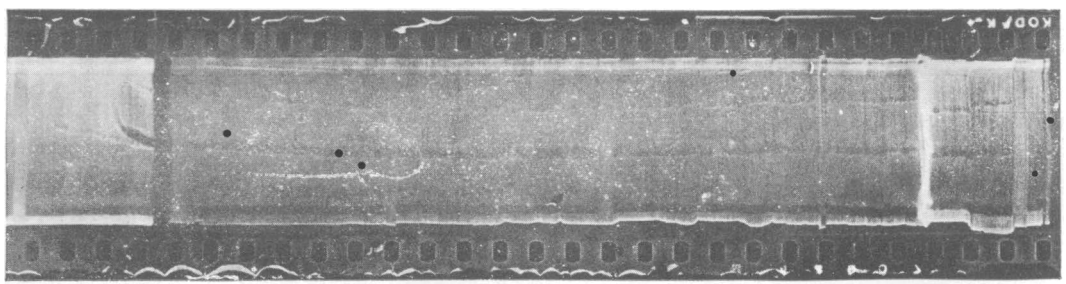


FIG. 5.

tion characteristic. The fact that the method is visual is a distinct advantage and a valuable feature of the apparatus.

Fig. 1 gives the general view of the instrument; fig. 2 shows the decay of sound in the reverberation chamber as delineated on its viewing screen; while fig. 3 shows the trace of a mechanical recorder under identical conditions.

Besides the above for which the apparatus was developed, it can be employed as a high speed power level recorder.

Testing of acoustical materials.—Using the method of measuring the reverberation time of the reverberation chamber, the coefficients of sound absorption and noise reduction factors of a variety of acoustical boards manufactured in India and of carpets made in Bangalore have been measured.

Sound decay in cubical rooms.—A theoretical study of sound decay in cubical rooms is in progress.

Linear time base.—There is some room for improvement in the linearity of the linear time base ordinarily used for delineating wave forms on the screen of a cathode-ray oscillograph tube. To secure as nearly perfect linearity as possible, an investigation was started some time back and is nearing completion. The principle employed is as follows.

In the usual C-R timing circuit, the voltage developed across either element varies exponentially with time. If the voltage indicating device contains a circuit element which takes the logarithm of the input voltage, its output will then be a linear function of time. A triode with a positive grid whose volt-ampere characteristics obey the law $v = a \log i + k$ is employed. As the current i will be proportional to the applied exponential voltage (from the C-R charging circuit) the voltage v across the triode will be truly proportional to time.

As compared with the usual type of time base, a larger sweep time is obtained for a given condenser; this is because the major portion of the charging stroke is utilized contrary to the usual practice of early triggering which makes linearity possible. This means that for slow sweeps comparatively smaller capacitors may be employed.

Ultra-High Frequency Work

Radio communication at high frequencies between 30 and 300 mega-cycles per second has been growing rapidly in recent years, and apparatus and technique are constantly being improved to secure reliability in service. The powers of the transmitting stations have also gone up. These developments require investigation into a variety of problems, such as the dielectric constants and conductivities of sea water and of different types of soils, the dielectric properties of solid insulating materials, the behaviour of electronic tubes at ultra-high frequencies and so on. The following deals with the investigations that have been conducted and are in progress.

Transit time effects in triodes used as negative grid oscillators.—One of the important features which limits the use of a triode at ultra-high frequencies is the transit time of the electron, *i.e.*, the time it takes in its flight from the cathode to the anode. Tubes have therefore been specially designed in which the transit times are made very small so that they can be used efficiently at ultra-high frequencies. As such tubes are not easily available in India, an investigation was started to determine experimentally the possibility of using some of the existing tubes to generate these oscillations, and also to find out the highest frequencies at which these tubes can give about ten per cent. of their maximum rated power. The tubes tested were 833-A, 834, 835, etc. The results of the tests showed that 833-A which is rated to give maximum output up to 30 megacycles can be used up to 210 megacycles to give 10 per cent. of this maximum output; the 834 tube gives its rated output up to 100 megacycles per second; it has been found that the highest frequency at which it will give 10 per cent. of this power is 190 megacycles per second. Similarly the tube 835 which can deliver the maximum rated power up to 15 megacycles can be used up to 172 megacycles to give ten per cent. of this output.

Absorption of ultra-high frequency waves by sea water.—A good part of radio communication is across the seas and it is, therefore, important to determine the absorption characteristics of sea water at ultra-high frequencies. The results that have been obtained show that the absorption index varies from 00.44

to 0·048 over a frequency range of 300 to 500 megacycles per second, with a maximum value of 0·06 at 380 megacycles per second; the reflection coefficient varies very little (0·67 to 0·675) over the same frequency band. The refractive index and conductivity have been found to vary from 10 to 10·6 and from $1·45 \times 10^{-2}$ to $3·6 \times 10^{-2}$ mhos per cm.[3] respectively over the frequency range.

Dielectric properties of solid insulating materials.—For ultra-high frequency work, insulating materials must have low loss factor and low temperature coefficient of dielectric constant. It is also essential that the dielectric constant and power factor of the materials should not vary much with moisture content and temperature. Ten different materials have been studied over a frequency range of 210 to 750 megacycles per second. The dielectric constants and power factors of ebonite and fibre have been found to increase rapidly with increasing percentage of moisture content. Plexiglass (methylmethacrylate) and mica are found to possess low loss characteristics at ultra-high frequencies.

Electrical constants of soil at ultra-high frequencies.—This investigation which is in progress has for its object the measurement of the dielectric properties of different types of soil having different moisture content, as well as their reflection coefficients at different angles of incidence. Horizontally polarised waves are used for the experiment.

Radio Wave Propagation

Radio wave propagation has always interested the workers of this Department. In the earlier days measurements were made of the received field intensities of long wave radio telegraph and medium wave broadcasting stations. Later with the development of medium wave broadcasting in India, their probable service areas attracted attention and the question of ground wave propagation came up. Also ever since the Polar Year of 1932, propagation of radio waves through the ionosphere came into the picture and apparatus was set up for the continuous recording of ionospheric echoes on a single frequency on a 24 hour basis.

Ground wave propagation curves.—Radio waves radiated from a transmitting antenna are propagated partly over the ground

and partly through the atmosphere (ionosphere) of the earth. The ground wave energy gets gradually absorbed by the soil on account of its finite conductivity, and the signal strength falls off with distance. The higher the frequency of the wave and the lower the conductivity of the soil, the greater is the attenuation; these two factors, the frequency of the station and the conductivity of the soil (and its dielectric constant) therefore determine the useful service range of a station. An agriculturally fertile soil has a higher conductivity (10^{-13} c.g.s.e.m.u.) than a poorer soil, and a rocky or sandy soil has the lowest conductivity of all (10^{-15} c.g.s.e.m.u). Sea water has the highest conductivity (10^{11} c.g.s. e.m.u) and radio waves travel farthest over the sea, *i.e.*, with the least attenuation for a given frequency and distance. Cities with reinforced concrete buildings are very unsatisfactory for ground wave travel, and correspond to propagation over low conductivity soil.

Sky waves are subject to fading and to diurnal and seasonal variations; they are also subject to the influence of terrestrial and extra-terrestrial occurrences, like magnetic storms, sunspots, etc. Ground waves, on the other hand, are affected by none of these; and frequency and distance from the transmitting station remaining the same, they are of constant intensity irrespective of the time of the day or the season of the year.

This is why the radio engineer favours ground wave service for a medium wave broadcasting station; its useful service area is reckoned in terms of its ground wave signal in relation to noise; its antenna is designed to concentrate its radiation along the ground. Over many years, mathematicians and radio engineers have investigated the problem of wave propagation over the ground in terms of the frequency of the wave and the conductivity and dielectric constant of the soil. The present curves (not reproduced here) on ground wave propagation have been drawn for five types of soil, *i.e.*, for five values of the conductivity and dielectric constant. They bring out strikingly the way in which the signal falls off with distance; they also show the effect of frequency and the constants of the soil on the signal intensity. Such curves furnish the basic data indispensable to the radio engineer and enable him to decide on the power of the station

and its frequency (if a choice is available), and the design of its antenna to secure the best possible service area.

Dispersion and polarisation curves.—Due to the presence of the earth's magnetic field, the ionosphere which is a region containing free electrons becomes a doubly refracting medium. A plane polarised wave passing through it therefore undergoes magneto-ionic splitting into two components, the ordinary and the extraordinary rays. These two component rays follow different paths, have different phase velocities and undergo different attenuations and changes in their angles of polarisation. The two rays are, in general, elliptically polarised and in opposite directions. The loss in wave energy is due to the collisions between the electrons which are set in motion by the wave and the molecules or atoms in the medium. These quantities relating to the wave, namely, dispersion, polarisation, absorption, etc., vary with the frequency of the wave, the electron density, the collision frequency between the electrons and the molecules, and the direction of the wave travel in relation to the earth's magnetic field. In particular, this last may be vertical, parallel to the magnetic field or perpendicular to it and so on.

These are expressed in the Appleton-Hartree formula for the square of the refractive index of the medium. Omitting collisional friction, this formula has been used to calculate the dispersion and polarisation curves (not reproduced here) against the electron density for a number of frequencies (16, 75, 1,000, 2,000, 4,000 and 8,000 kilocycles per second). This has been done for different directions of wave travel in relation to the earth's magnetic field—longitudinal, transverse, vertical, and horizontal both in the east-west and north-south directions. The magnetic field components are those for Bombay.

These curves bring out in a very clear manner the way in which the radio wave is affected in its passage through the ionosphere. Experimental observations have borne out strikingly the soundness of the magnetic-ionic theory put forward by Appleton and Nichols.

Ionosphere measuring apparatus.—The pulse method originated by Breit and Tuve in 1926 for the investigation of the ionosphere has developed into a powerful tool thanks to which a

great amount of knowledge of the highest scientific and practical value has been obtained about the structure and properties of the ionosphere and of radio wave travel through it.

The principle underlying the method is simple. A transmitter radiates pulses of radio waves of about 100 to 200 microseconds duration and occurring regularly, say, every 1/50th of a second, *i.e.*, at the frequency of the supply mains. These reach the ionosphere and are reflected from it back to the ground. With vertical incidence, the echo is received at the same place as the transmitter, and observed directly on the screen of a cathode-ray oscillograph, or is recorded on a moving photographic film. The time delay between the sending of the pulse and the arrival of the echo gives the effective height of the ionosphere. By varying the frequency of the transmitter and following these variations on the receiver, the incident wave is observed to undergo magneto-ionic splitting into the ordinary and the extraordinary waves; the critical penetration frequencies of these are obtained or recorded on the photographic film. These observations give a good deal of information regarding the ionosphere.

At a number of centres in different parts of the world, such observations are being made continuously on specially designed automatic recording apparatus. The data obtained are of great practical value as they enable one to forecast a few months ahead the frequencies that are likely to be satisfactory for radio communication on short waves at different parts of the day and over different distances.

The apparatus now being set up at the Institute is the second of its kind, and manually operated. It runs off the a.c. mains supply and does not require any other supply. It has no moving mechanical parts and is purely electrical. Only vacuum tubes are used in the apparatus including the pulse generator, as gas tubes were found to be rather unsatisfactory with fluctuating mains voltage. The transmitter is of the self-oscillator type and uses two 125 watts tubes in push-pull; and it is series modulated. A ready made receiver with a band width of 16 kilocycles in the intermediate frequency amplifier stages is used and the output of the intermediate frequency amplifier is further amplified by an external amplifier tuned to this frequency. The output of this

external amplifier is directly connected on to the deflecting plates of the cathode-ray oscillograph without any further detection and amplification.

The pulses are derived directly from the a.c. supply mains without any need for the usual synchronizing arrangement. And a switch has been included in the pulse generator by means of which the successive parts of the circuit can be switched on to a test cathode-ray oscillograph to illustrate how starting from the 60 cycles sinusoidal mains voltage the final pulse of the same recurring frequency is obtained. This arrangement is found to be very helpful as it traces the process from stage to stage. It is also useful in detecting quickly any fault or failure that may develop in any part of the pulse generator.

On a few previous occasions, continuous 24-hour observations were made of the heights and critical penetration frequencies of the F_2 layer. These have been plotted on charts (not reproduced here) and show the usual diurnal variations, the critical frequency rising up to a maximum in the late afternoon and going down to a minimum in the early hours of the morning before sunrise. These apart, there is a marked increase in the critical frequencies from December 1944 when the first observations were made up to the summer of 1948 the time of the last measurements. This is to be expected as these have been years of increasing sunspot activity.

Figs. 4 and 5 are records of echoes on 4 megacycles per second. Multiple echoes from the F_2 layer are clearly marked in one and the magneto-ionic splitting of the echo in the form of a forking on the other.

A manual ionosphere measuring apparatus has its undoubted advantages; but making observations on a 24-hour basis and day after day is very monotonous to the operator, and expensive. An automatic recording method is very convenient and economic, and has been adopted wherever continuous 24-hour observations are made throughout the year. It is hoped to develop at the Institute such an apparatus when the necessary facilities are available.

Pulse modulation.—The methods of modulation that have been and are being used till now have for their starting point the

continuous wave of constant amplitude and frequency. The modulation or signal (speech, music or telegraphic signal) modulates suitably one or other of the three characteristics of the continuous wave, its amplitude, frequency or phase. The most common of the three is amplitude modulation, and it is used in the great majority of transmitters all over the world. The use of frequency modulation is growing, particularly in the U.S.A. and to a lesser extent in Great Britain, as it gives a better signal in relation to noise. Phase modulation as such is not used.

Since about a decade or so, a different method of modulation is being developed, namely, pulse modulation. The transmitter radiates the radio wave not as a continuous wave, but in pulses; in between the pulses, there is no radiation. In the absence of the signal, these pulses are of constant amplitude and duration and occur at equal intervals of time. The pulse duration (or width) is generally of the order of a few microseconds; and the pulse recurrence frequency is several times the highest frequency of the modulating signal. When the signal comes on, it varies either the amplitude of the pulse, its width, its position (or timing) or the frequency of its recurrence in accordance with the intensity and frequency of the signal. The modulated pulse so obtained is put on to an ultrashort wave or microwave transmitter which therefore radiates the radio wave in pulses. At the receiving end, the process is reversed and the signal (speech, music or telegraphic signal) is recovered and passed on in the usual way. This can be done in one of several ways.

Pulse modulation has several advantages in its favour; it is superior to amplitude modulation in the matter of signal-to-noise ratio; and what is not less important, it can be used for multiplex working.

The apparatus that is being set up at the Institute uses pulse position (or time) modulation. A square wave generator is used to produce pulses of a few micro-seconds duration and a recurrence frequency of 10,000 times a second; this means that in the absence of modulation successive pulses are spaced equally 100 microseconds apart, a convenient spacing for commercial telephony for which the transmission band is between 300 and 3,400 cycles per second according to the C.C.I. When modulation is

applied, the positions (or the timing) of alternate pulses are shifted, the amount of the shift being proportional to the instantaneous value of the signal or modulating wave. After suitable amplification, the modulated series of pulses can be used to key a transmitter of appropriate frequency.

In the pulse receiver, the input pulses are just similar to the ones applied to the transmitter for modulating it. They are used to trigger two triodes connected anode to grid through resistances. These triodes will give rectangular waves at the anode and these are passed on to a suitable filter which delivers the signal at its output.

This apparatus which shows simplex working is just an elementary thing and merely illustrates the principle of one type of pulse modulation. There is plenty of fascinating work in the field.

In Great Britain and in the U.S.A., great progress has been and is being made in this field and several systems are being developed. During the war years, multiplex pulse communication has been used with excellent success.

High Frequency Bridge.—The problem of adapting the principle of the Wheatstone bridge for radio frequencies is by no means easy on account of the stray electric and magnetic fields associated with the different parts of the circuit. Shackleton investigated this question in detail and developed a system of careful shielding which greatly reduces many sources of error. Based on his analysis, and after further examination of the ratio arm errors, the present bridge has been designed and made; it uses carefully wound resistances for the ratio arms and the system of shielding evolved by Shackleton. It is found to be satisfactory up to a frequency of about 1·0 megacycles per second; at higher frequencies, the error increases. Like many other types of radio frequency bridges, this also uses the resonance method of measurement.

200 *Watt transmitter.*—This was designed and built during the war years at the instance of the Air Force. It can be controlled either by a crystal oscillator or by a master oscillator, and the frequency can be adjusted to any value between 6,500 and 7,500 kilocycles per second. It consists of the usual crystal (or

master oscillator, frequency doubler, and two stages of class C push-pull power amplifiers giving an output of about 200 watts. The transmitter can be used for both telegraph and telephone working.

As it was war time, many component parts, such as filament and anode supply transformers, were not available in the market and so were designed and manufactured at the Institute.

250 *Watt Modulator.*—This unit, the construction of which is nearing completion, consists of a driver stage feeding the output power amplifier, both of which are of the push-pull type. A modulation reactor is in the output of the final power amplifier and can be connected on to the transmitter to be modulated. The output stage works on 1,250 to 1,500 volts anode supply; the distortion is expected to be low and the frequency response uniform from 50 to 12,000 cycles per second. This unit is intended to be used for modulating any of the transmitters in the laboratory and will be used for the routine laboratory work of the students and for investigation work.

High frequency standard.—A satisfactory standard of frequency is perhaps the most vital requirement for any radio or telecommunication work. High precision and high stability of frequency are the two basic features in such a standard. It is used for the calibration of frequency meters, the precision measurement of the frequencies of radio transmitters, and for other purposes requiring accurate measurement of frequency. On account of their exceptional electro-mechanical properties, and their low temperature coefficients of frequency, the tuning fork made of the alloy elinvar or the piezo electric quartz is used as the basis of such a standard frequency equipment.

The apparatus at the Institute due to the late Dr. Dye of the National Physical Laboratory, England, and manufactured by H. W. Sullivan Ltd., of London, uses a temperature and pressure controlled tuning fork of elinvar and vibrates precisely at the rate of 1,000 cycles per second. The accuracy and stability of frequency of the fork are extremely high, the latter being of the order of a few parts in a hundred million. Apart from the tuning fork and its circuit, the apparatus consists of two multivibrators, a frequency selecting circuit, receiver, interpolation and extrapola-

tion oscillators, and means for checking the frequency of the fork against radio time signals.

The accuracy of measurement is in practice of the order 2 or 3 parts in a million; higher accuracies are possible if the frequency of the source under test is very stable.

This apparatus is the only one of its kind in India and similar ones are in use in England and in other parts of the world.

Information charts on broadcasting in India and abroad.— Radio broadcasting is a most important form of electrical communication of vital interest not only to the radio engineer but to the individual citizen in any part of the world. In Europe, North America and several other parts of the world, broadcasting has woven itself into the fabric of the daily life of the community and of the individual; it has permeated into almost every one of life's activity, not only as an instrument of education, entertainment and news, but also as an offensive and defensive weapon of war and of internal and external propaganda. It has become a most potent weapon of immense good when guided and controlled by men of goodwill, wisdom, foresight and knowledge, but of immeasurable harm in the hands of persons lacking in these qualities.

Although broadcasting was started in India almost immediately after it emerged as a public service in Western Europe and North America, it has always lagged very much behind these countries in practically every aspect of its development. India has a long way to go before it can be said to possess an efficient countrywide national broadcasting service of technical and programme quality comparable to those of the countries of the west.

The subject is well worth close study and to bring out the situation as it obtains to-day, the following coloured charts (not reproduced here) of the various aspects of broadcasting in India and abroad have been prepared. These do not give an exhaustive picture but are probably sufficient to illustrate the status of broadcasting in India in relation to other countries: (*a*) map of broadcasting stations in India, (*b*) growth of licensed receivers in India, (*c*) programme composition and programme hours of Indian stations per day and per week, (*d*) broadcasting stations in the different countries of the world, and (*e*) receivers in use in different countries.

List of Exhibits

A. Transmitter Laboratory

1. Reverberograph.
2. New type of Linear Time Base.
3. Apparatus for Control of Road Traffic Lights.
4. Strowger Demonstration Set for Automatic Telephony.
5. 200 Watt Short Wave Transmitter.
6. 250 Watt Modulator (under construction).
7. Demonstration of the reflection of ultra-high frequency waves.
8. Ground mine Detector.
9. Pulse modulation—Generator and Receiver (under construction).

B. Standards Room

1. High Frequency Standard Equipment.
2. Ionosphere Measuring Apparatus (under construction).
3. High Frequency Bridge.

C. Reverberation Chamber

1. Testing of Acoustical Materials.

Charts

1. Broadcasting in India and abroad (Corridor).
2. Ground Wave propagation curves (Transmitter Laboratory).
3. Curves of Dispersion and Polarisation of Radio Waves (Transmitter Laboratory).
4. Observations of Critical Frequencies and Heights of the Ionosphere (F_2 layer) (Transmitter Laboratory).

SOCIAL SCIENCES AND INDUSTRIAL ECONOMICS

The Section of Social Sciences and Economics, started in 1947, has for its objective the provision of instruction in social sciences and economics to the young technologists undergoing training in the various scientific Departments of the Institute. It is now well recognised that technologists and scientists, before entering industry as managers, experts, foremen, etc., should have a deep appreciation of modern trends in economics and human relations in order to utilise the human element involved in industry to the best advantage of society.

The Section includes a Bureau of Industrial and Statistical Information which collects and disseminates information of industrial and statistical nature to research institutions and industrialists in the country. In particular, it assists the research workers at the Institute in gathering relevant economic data and statistics in regard to the nature, magnitude and productivity of key industries in India which may be of use to them in their scientific investigations. It also attends to numerous enquiries for statistical information regarding scientific matter, and has gathered a large number of reports, statistical bulletins, periodicals and catalogues of firms not only in India but also abroad and maintains a sub-library, which is open to all, for consultation during working hours. It has recently undertaken to furnish relevant information to the Scientific Information Offices of UNESCO established in India.

This Section provides a series of lectures on industrial relations and psychology for the benefit of both students and research workers of this Institute. It invites distinguished experts in these subjects to deliver lectures on their special studies. Research of a scientific character into important current economic and social problems is also an activity of the Section. As one of the early investigations in the Section, a survey was made of the effect of prohibition on the personality of the industrial worker. Particularly the industrial worker is supposed to be mostly addicted to alcoholism, and a good share of industrial efficiency or otherwise should be presumably due to this. The questionnaire used

is meant to assess the personality of the worker as revealed by himself, a near relative, an associate and the employer. Another research topic is the measurement of the Security Index. Here an attempt is made to analyse the possible sources of the feeling of insecurity such as the physical, social, economic, familial, ethical, religious, etc. This aims to arrive at the probable factor contributing to human unrest and the relative magnitude of these. The Ink-Blot Tests, which are well-known personality (projection) tests are revised so that scope is now afforded for exercising the inventive or creative faculty, the subjects being asked to complete partial blots. In brief, the Section is organizing a laboratory of industrial psychology (equipment for the same is being received), not only to give the necessary training in the experimental technique with reference to industrial problems, but also to be of immense use to students and members of the staff to carry on researches. An association called the Social Sciences Seminar has been started with the object of stimulating interest in the studies of industrial and social problems, and includes members of all the Departments.

Given below is a list of Exhibits of the Section:

A. Charts

No. 1. Yearly production of certain important industries in India comprising of the following:—

(1) Cotton piecegoods, (2) Cement, (3) Sulphuric Acid, (4) Sulphate of Ammonia, (5) Paper, (6) Sugar, (7) Pig Iron, (8) Steel Ingots, (9) Finished steel.

No. 2. Yearly production of certain important minerals in India:

(1) Coal, (2) Petrol, (3) Kerosine, (4) Manganese, (5) Gold, (6) Mica, (7) Bauxite, (8) Iron ore.

No. 3. Yearly production of principal Agricultural Commodities comprising of:

(1) Rice, (2) Wheat, (3) Sugarcane, (4) Cotton, (5) Jute, (6) Groundnuts, (7) Sesamum, (8) Linseed, (9) Rape and Mustard, (10) Castor seed, (11) Tobacco, (12) Tea, (13) Coffee, (14) Rubber.

No. 4. Labour Power in India showing the distribution of labour according to the major industries and according to the provinces: and the average earnings of Factory workers according to provinces.

No. 5. *Industrial Relations* showing the number of industrial disputes in India.

Economic barometers

Graphical representation of the cost of living index numbers at certain important industrial centres in India: *viz.*, (1) Bombay, (2) Kanpur, (3) Madras, (4) Bangalore.

B. Apparatus

Industrial psychology and relations

(*a*) *Tests of intelligence.*—One of the most essential characteristics of intelligence is adaptation to the changing environment; it also implies the acquisition of new modes of behaviour. Thus a workable definition of intelligence would be "the capacity to learn". It is suggested by some that there are three types of intelligence—abstract (ability to acquaint oneself with symbols and concepts), social (ability to move and live amid people) and mechanical (ability to manipulate tools and other material things so as to be useful). Although the potential possibility appears to be determined by heredity and constitution, the role that training plays in the maturation of intelligence cannot be lost sight of.

I.Q.—Intelligence exhibits itself in different individuals in different amounts: it varies from a very low degree to definitely superior degree. It is thus of the form of a scale and distributes itself in a normal curve of probability. Tests have been devised to measure the amount of intelligence that is at the disposal of an individual. Emphasizing the degree of correspondence between the actual (chronological) age of an individual and his mental age (on the result of the scores obtained from the tests) the concept of Intelligence Quotient (I.Q.) has been evolved. It is simply defined as MA/CA. The I.Q. of an average individual should normally be 1: but for purposes of mathematical convenience it is multiplied by 100. Below 100 means subnormality, while above it denotes superiority.

Tests

(*a*) Tests of intelligence roughly fall into two types: verbal and non-verbal; the former, for the use of literates and the latter for the use of illiterates and those not acquainted with the language of the test. The verbal tests make use of words and sentences and the subject or testee is asked to answer in words and sentences. The non-verbal tests are also called 'performance tests', wherein the testee is expected to answer by way of handling certain blocks, arranging them, manipulating them, etc.

(*b*) Besides these tests which measure general intelligence many tests have been devised that are intended to detect and measure what are called "special abilities". Tests of mechanical ability form a wide group: they test the 'level of achievement' possible for the testee as well as 'the extent to which the candidate is fitted to perform the requirements of jobs'. Tests of motor aptitude and motor co-ordination or manual dexterity are of great value in selecting men for jobs and fitting jobs for men (vocational guidance). Other industrial tests are:

1. 'Tapping Test' measures the speed of movement. The testee taps on a metal plate with a metal stylus; and the number of taps in a given time is the score.

2. 'Steadiness Tester'. The testee should insert a metal stylus into a series of 9 successively smaller holes in a metal plate, without touching the rim of the hole (see photograph).

3. 'Ergograph' is intended to measure fatigue. The testee is to lift a definite weight by his finger at regular intervals; after a time, fatigue sets in and unless the weight is reduced he cannot lift at all; and even then fatigue sets in quicker.

4. 'Phi-phenomenon box'. The familiar illusion of motion pictures is the theme of this test: this illusion of movement could be used with great advantage in advertisements.

5. Manual dexterity tests.

6. 'Two-hand Co-ordination Test' is an aptitude test for jobs like lathe-operation where two different types of operations are to be performed by the two hands (see photograph).

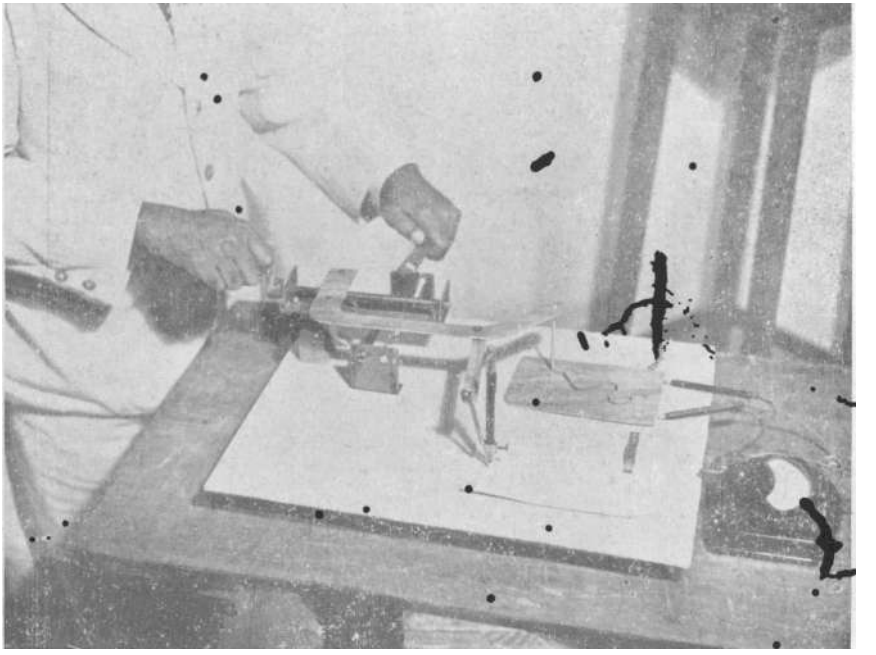
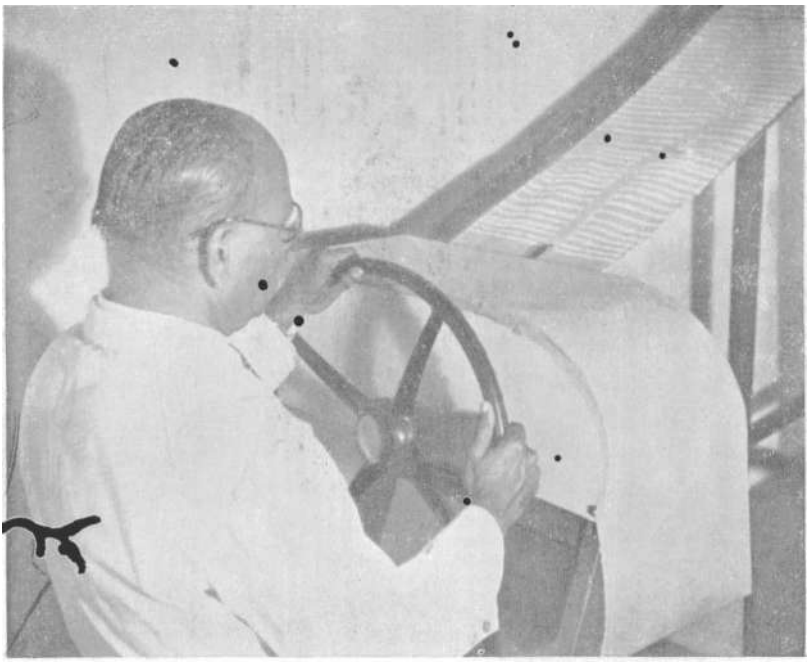
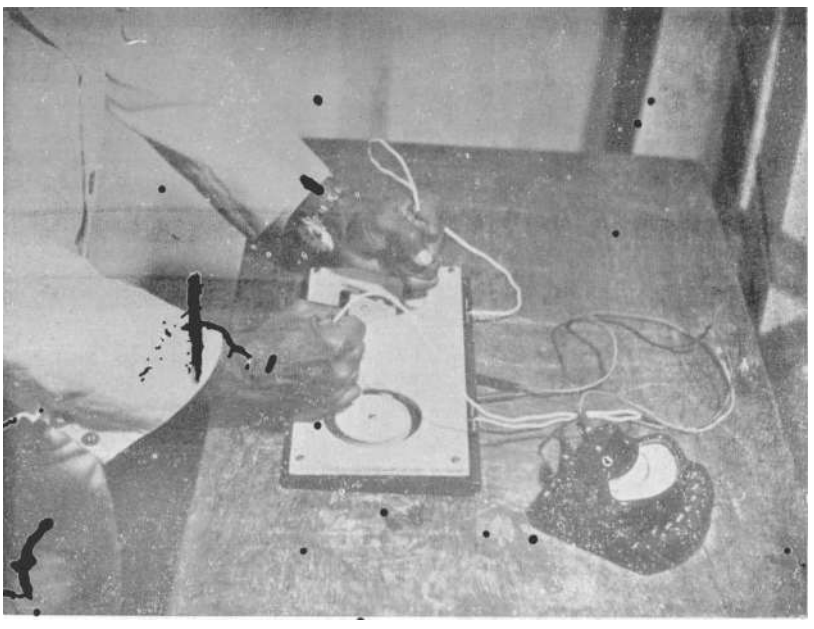


PLATE XXVI



Motor driver's test



Division of vibration test

7. 'Winking-glass test' measures the will-factor of an individual; his ability to sit without winking when a bar hits on a glass screen placed before his eyes.

8. 'Tachistoscope' tests the span of attention: it measures what number of items a man can grasp within a definite, small span of time.

9. Motor Driver's Test.

(*c*) The above-listed are industrial and vocational tests. Besides these there are general tests such as:

1. Ink-blot test, to measure the capacity of the individual to interpret the unmeaning blots. The number of interpretations in a definite time is the score.

2. Mirror-Direction Test, to measure the ability of the testee to grasp and respond to a new situation, *i.e.*, to learn the new relations of directions as viewed in the mirror.

3. Division of attention: This is to find out how successfully tasks of dissimilar nature could simultaneously be performed by an individual (see photograph).

4. Step-maze is the hidden pattern which the testee is required to learn by insight in practice. The time taken to achieve mastery is the score.

5. *Perceptoscope*: An apparatus designed to show different stages in the act of visual perception.

CHARTS

1. What makes a job interesting.
2. The wishes men live by: Four wishes of man.
3. Types of human appeal.
4. Motives of the Factory worker.
5. Motives of man.
6. Job and Intelligence.
7. Our obligations to our country.
8. Pathways of progress.
9. Personality values.
10. Effect of alcohol on Personality.

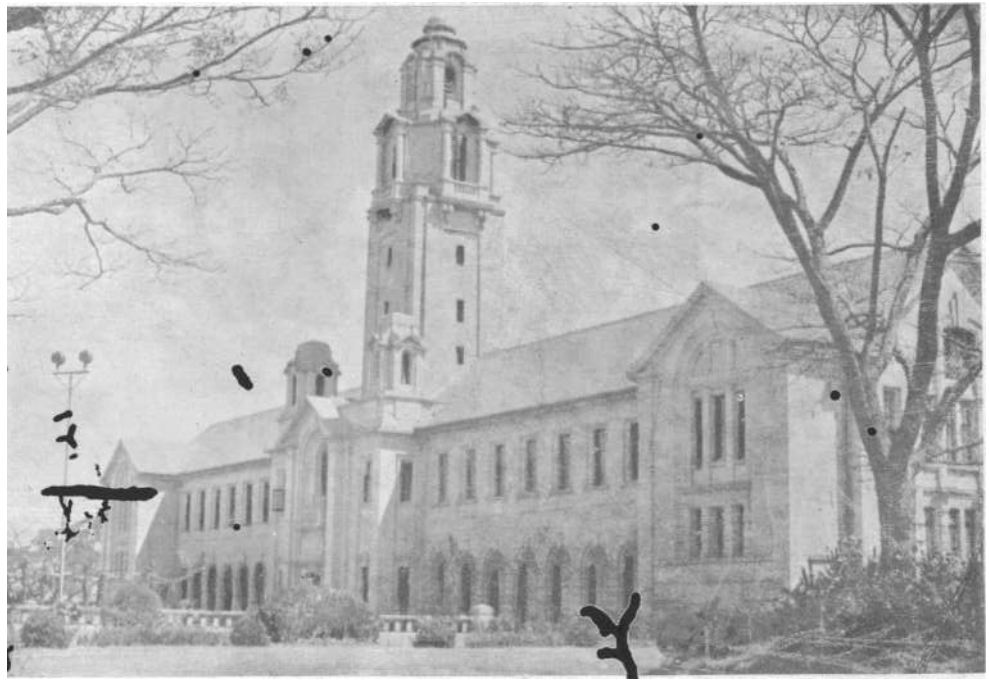
THE LIBRARY

The Library of the Indian Institute of Science, Bangalore, forms one of its finest features and this Special Number will not be complete without a reference to its arrangements and the facilities it provides to investigators not only in Bangalore but all over India. It is devoted especially to physical sciences, both pure and applied, and also to biological sciences so far biochemistry and pharmacology are concerned. In recent years, it has extended its scope considerably in engineering sciences, particularly, aeronautical engineering, internal combustion engineering and metallurgy and has included also economics and social sciences. The Library has given outstanding assistance to the prosecution of research work in all the Departments and has played a notable part in the achievements of the Institute in important scientific investigations. So far as technical publications and documentation of scientific work are concerned, the Library is not excelled in the country. Exhibits of the first volume of the Philosophical Transactions of the Royal Society of London (dated 1665) and the first volumes of the Proceedings of the Academies of France, Germany and Italy, and the collection of the Journal of the Institute and theses submitted by students of the Institute at Stands 1 and 2 will be found interesting. An exhibit of the documentation on the history and development of atomic power is placed at Stand 3 in Room No. 1. The Library has recently been procuring also scientific films as a visual aid to understanding various technological problems and the film on Atomic Physics will be exhibited during the Exhibition in the same room (Room No. 1).

SITUATION

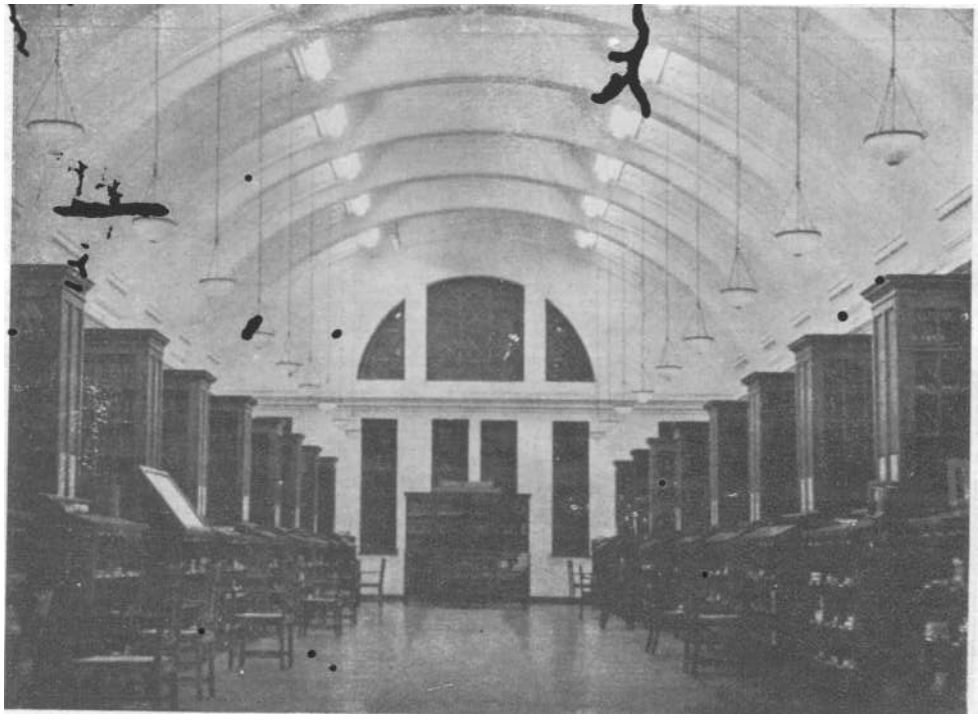
The topographical situation of the Library is delightful, the selected location being probably the best that could be found in India and enjoys an elevation of 3,050 ft. The green expanse of the Institute grounds is dotted with laboratories, workshops, hostels for students and bungalows for the teaching staff. The Library is housed on the first floor of the central building, overlooking the sweet and peaceful surroundings (see Plate XXVII)

PLATE XXVII



The Library Building

PLATE XXVIII



Interior view of the Library

The Library consists of high, arched spacious wings which are its reading rooms. One enters the western wing between massive, glass-paned almirahs which, like an avenue, lead up to the Latest Additions Shelf where all new acquisitions are exhibited under two headings: Reference Works and Latest Additions. On either side of the Latest Additions Shelf are placed standard works of reference in different branches of science. Nearby, stand series of old and new encyclopædias and technical dictionaries. The walls of this hall are lined—except under the large windows—with almirahs at right angles to which are placed journals stands, each containing 18 scientific periodicals. Near the almirahs in the eastern wing are hung large portraits of eminent scientists; these portraits were procured by the Library. Recently, the Imperial Chemical Industries Ltd. have, through the courtesy of their Eastern Countries Office, presented the Library with eight portraits of scientists of international repute; these will be placed in the western—the main—hall of the Library. The Institute greatly appreciates this gesture. The total area of the two wings of the Library is some 8,000 sq. feet. At the entrance of each wing, one finds the cards catalogue cabinets, the older of which are being replaced by standard sized card cabinents; these are followed by the same avenue of almirahs, and spaces between two almirahs are being used as cubicles where tables and chairs are arranged for individual readers. The two wings and balconies together can comfortably accommodate some 100 readers at a time. Plate XXVII shows the exterior view of the Library on the first floor of the main building and Plate XXVIII the interior view with fluorescent illumination.

Book-store, Micro-films, Film-strips

The total stock of books, serials, works of reference and Government publications is estimated at about 37,000 (*vide*, last Report, 1947–48). Of this, some 28,770 or so are bound volumes of back numbers of scientific periodicals in almost all the important European languages. Complete sets of scientific periodicals are the pride of technical libraries and one of the sets of some 1,000 current periodicals and periodical publications available in the library dates back to 1665. There is also an interesting collection of Indian, British and German patent specifications and

B.I.O.S., C.I.O.S. and F.I.A.T. reports dealing with applied research carried out in Germany in the last war. More than 150 micro-film copies of German journals of the war period are available for consultation in the library. These will be seen together with a micro-film reader, at Stand No. 4. The library has procured whenever necessary film-strips (biblio-films). A film-strip projector, kindly presented to the library by the American Consul, Madras, will be seen in use at Stand No. 5. It is a well-known fact that in technical libraries books form only a small part of their contents, and this same rule applies to the library of the Indian Institute of Science. The remainder of the stock consists of periodicals, periodical publications and monograph series. The stock is being constantly increased with purchases and with valuable gifts from Universities, Learned Societies, and private donors. Comprehensive surveys of new publications are made, in anticipation of readers' requirements, with the help of reviews and references in current issues of technical journals, "Abstracts", cumulative book-lists, publishers' notices, book-forecasts and previews, and new publications are acquired on recommendations from Heads of the Departments of the Institute. It is proposed to publish these lists and circulate them to other scientific institutions in the country. While a few French and German dictionaries are kept at the Counter at the disposal of readers, an important nucleus of books in these and other languages as well as on library science is being developed in the now enlarged room of the Librarian.

Since 1940, information regarding "Journals received" and new acquisitions of the library was supplied to all the departments of the Institute by means of daily, weekly and fortnightly accession lists. Readers have unrestricted open access to shelves, and members of the Institute can have on loan any new book or current issue of periodical on the fifteenth day from the date of its shelving. The rather limited public served by the library (about 500 in number at the outside) makes it possible to have an elaborate loan record and to get prompt answers to the fundamental questions regarding counter work mentioned in any library primer. The number of books issued on loan during 1947–48 was 6,206, that of the bound volumes of journals issued to the Heads of Departments was 312.

Photostat Service

In order that a wide use be made of the collections of the library, typed copies of articles from journals and books were supplied to research workers all over the country till 1947. In the beginning of 1948, a photostat apparatus was installed and the library is in a position to supply photostat copies or photo-copies of material from the periodicals included in its extensive list. The library is anxious to extend this photostat service to make its rare and unique resources accessible to as many investigators in the country as possible. Investigators who wish to have photo-copies of scientific material for their own private use are requested to send to the Librarian full reference of the paper, *i.e.*, name of the author, title of paper, name of the journal in which the paper is published, page number, together with the number of the volume and year of publication of the journal. A nominal fee is charged for photo-copying which varies with the size of the material. Specimen photostat copies are on exhibit at Stand No. 6.

Catalogues

The principal catalogues of the library consists of the following sections:—

(*a*) Alphabetical author catalogue (card catalogue).
(*b*) Classified subject catalogue (card catalogue).
(*c*) Classified subject catalogue (in sheaf form).
(*d*) Alphabetical shelf-list catalogue (card catalogue).

The books are catalogued on cards of international standard size according to the Anglo-American code contained in Catalogue rules; author and title entries, Chicago". The publications of Institutes, Societies, Academies and analogous bodies are found under the first word (not the article) of the name of the body. The classified subject catalogue o the library has a special scheme of classification of its own for sciences.

Foreign Languages and Translation Service

This service has grown to the extent that a full-time lecturer in European languages has been recently appointed. Translations are made from most European languages of technical reports and articles in the foreign scientific periodicals which are consi-

dered to be of interest to staff and students of the Institute. Students are given instruction in French and German and this is supplemented by practice of phonetics by means of a Magnetic Wire Recorder, which is kept on Exhibit (see Exhibit No. 7) as well as by the Linguaphone system. Contents and short summaries of articles from journals in Russian are translated and circulated to all departments of the Institute. Translations are also made and supplied to investigators and institutions throughout the country for their own private use. Investigators requiring a translation may send a requisition either to the Librarian of the Institute or to the Lecturer in European Languages giving full reference of the paper as in the case of photocopies referred to above.

The Library of the Indian Institute of Science, Bangalore, is truly an *instrument de recherches scientifiques* like the best science libraries in Europe and America. In India, it is an important centre of technical literature and bibliographical research. It is a young and growing institution and requires considerably more growth and fulness. So far as the physical sciences, pure and applied, are concerned documentation is tending to become centralized in this library. It will be in the fitness of things if such a library will enhance its utility as an instrument of scientific research by compiling repertories and by building up a regular information service within its special scope and in close co-operation with other scientific and technical libraries in the country, an objective which is constantly kept in view. The library has recently established close *liaisons* with the British, American and Australian Science Information Services as well as that of the UNESCO office in Delhi.

Given below is a list of the Exhibits in the Library.

(1) (*a*) First volume (dated 1665) of the Philosophical Transactions of the Royal Society of London; (*b*) First volume of the *Comptes Rendus de l'Academie des Sciences*, Paris.

(2) Collection of the Journal and Quarterly of the Indian Institute of Science, Bangalore.

(3) Collection of theses submitted by students of the Indian Institute of Science, Bangalore.

(4) Micro-film Reader and micro-films of German journals of the war period.
(5) Micro-film projector and film strips.
(6) Photostat machine in operation and photocopies.
(7) Linguaphone and Magnetic Wire Recorder.
(8) Documentation on the history and development of atomic power.
(9) Projection of the film: Atomic Physics.

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